



IMBER Open Science Conference

FUTURE OCEANS

23-27 June 2014 _____

_____ **Bergen, Norway**

Research for marine sustainability:
multiple stressors, drivers, challenges
and solutions

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IMBER Open Science Conference

Future Oceans

Research for marine sustainability:
multiple stressors, drivers, challenges and
solutions

22-27 June 2014
Bergen, Norway

Produced by: IMBER International Project Office
IMBER Regional Project Office

Cover design: Sébastien HERVE - contact@sebastien-herve.com

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IMBER OSC 2014 programme – Overview

Click [here](#) to see the general programme

Organisers

Scientific Organising Committee:

Eileen Hofmann (Chair): Old Dominion University, USA

Ratana Chuenpagdee: Memorial University of Newfoundland, Canada

Julie Hall: National Institute of Water and Atmospheric Research, New Zealand

Raleigh Hood: University of Maryland, USA

Ian Perry: Fisheries and Oceans Canada, Canada

Carol Robinson: University of East Anglia, UK

Bernard Avril: IMBER International Project Office, Norway

Local Organising Committee:

Dag Aksnes: University of Bergen, Norway

Beatriz Balino: University of Bergen, Norway

Ken Drinkwater: Institute of Marine Research, Norway

Tore Furevik: University of Bergen, Norway

Christoph Heinze: University of Bergen, Norway

Svein Sundby: Institute of Marine Research, Norway

Lisa Maddison: IMBER International Project Office, Norway

IMBER International Project Office (IPO):

Institute for Marine Research, Bergen, Norway

Bernard Avril

Lisa Maddison

Turid Loddengaard

Veslemøy Kjersti Villanger

IMBER Regional Project Office (RPO):

East China Normal University, Shanghai, China

Liuming Hu

Fang Zuo

Sponsors

[Academia Europaea](#)

The Academy of Europe is a European, non-governmental association acting as an Academy. Our members are scientists and scholars who collectively aim to promote learning, education and research. Founded in 1988, with about 3000 members which includes leading experts from the physical sciences and technology, biological sciences and medicine, mathematics, the letters and humanities, social and cognitive sciences, economics and the law.



[Aquatic Biosystems](#)



AQUATIC BIOSYSTEMS

Aquatic Biosystems, published by BioMed Central, is an open access, peer-reviewed, online journal considering high quality manuscripts on all aspects of basic and applied research on aquatic organisms and environments.

The scope of Aquatic Biosystems ranges from the molecular and organism levels to global systems and processes. The journal encourages reports on a wide array of environments, including lakes, rivers, marshes, springs, lagoons, solar pans, estuaries, and the open ocean, and their micro- and macro-flora and fauna. The focus is on the relationships between the environment and biological systems, encompassing microbial genomics, physiology, and ecology, biogeochemical cycling, food webs, paleolimnology, biodiversity, conservation, resource management, and ecosystem structure and function. Engineered biosystems, such as for aquaculture, renewable resource, biofuels, biotechnology, and biomedical production, as well as constructed wetlands, are within the scope of Aquatic Biosystems.

The goal of the journal is to bridge across freshwater and saline systems, between basic and applied research, and from gene systems to ecosystems. The online format of the journal is designed to accelerate the process of disseminating important research results and information, in order to better meet the needs and demands of the highly dynamic and global science, management, and private sectors.

[City of Bergen, Norway](#)

The municipality of Bergen, Norway's second largest city with a population of 300 000, kindly sponsors the conference reception to take place in the 750 years old Håkonshallen, once the royal residence and banquet hall of viking King Håkon Håkonsson.



BERGEN KOMMUNE

Sponsors

[East China Normal University](#)

ECNU is one of the China's key universities under the Ministry of Education of the People's Republic of China and supported by the national programs on key universities "Project 211" and "Project 985". Currently, the University contains 21 schools and colleges and 5 research institutes, with 58 departments offering 70 undergraduate programs, 38 master's programs and 26 doctoral programs of the State Primary Disciplines. The total number of full-time undergraduate students and graduate students is about 15,000 and 12,000, respectively.



[European Geosciences Union \(EGU\)](#)



The European Geosciences Union (EGU) is Europe's premier geosciences union, dedicated to the pursuit of excellence in the geosciences and the planetary and space sciences for the benefit of humanity, worldwide. It is a non-profit international union of scientists with over 12,500 members from all over the world. Membership is open to all who are professionally engaged in or associated with geosciences and planetary and space sciences and related studies. Its annual General Assembly is the largest and most prominent European geosciences event, attracting over 11,000 scientists from all over the world. The meeting's sessions cover a wide range of topics, including volcanology, planetary exploration, the Earth's internal structure and atmosphere, climate, as well as energy and resources.

[European Space Agency](#)

The European Space Agency (ESA) aims to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. ESA's job is to draw up the European space programme and carry it through. ESA's programmes are designed to find out more about Earth, its immediate space environment, our Solar System and the Universe, as well as to develop satellite-based technologies and services, and to promote European industries. ESA also works closely with space organisations outside Europe.



[Future Earth](#)

Future Earth is the global research platform providing the knowledge and support to accelerate our transformations to a sustainable world. Launched in June 2012 at the UN Conference on Sustainable Development (Rio+20), Future Earth is a 10-year international programme that will build and connect global knowledge to intensify the impact of research and find new ways to accelerate sustainable development. Future Earth



Sponsors

will be an international hub to coordinate trans-disciplinary approaches to research, ensuring that knowledge is generated in partnership with society and users of science.

[Gordon and Betty Moore Foundation](#)



The Foundation forms and invests in partnerships to achieve significant, lasting and measurable results in environmental conservation, and scientific research around the world, as well as helping to improve the quality of life in the San Francisco Bay area.

[International Council for Science \(ICSU\)](#)

The International Council for Science (ICSU) is a non-governmental organisation with a global membership of national scientific bodies (121 Members, representing 141 countries) and International Scientific Unions (31 Members).



ICSU's mission is to strengthen international science for the benefit of society. It does this by mobilising the knowledge and resources of the international science community to:

- Identify and address major issues of importance to science and society.
- Facilitate interaction amongst scientists across all disciplines and from all countries.
- Promote the participation of all scientists—regardless of race, citizenship, language, political stance, or gender—in the international scientific endeavour.
- Provide independent, authoritative advice to stimulate constructive dialogue between the scientific community and governments, civil society, and the private sector.

[Institute of Marine Research, Norway](#)

IMR is Norway's largest centre of marine science. Its main task is to provide advice to Norwegian authorities on aquaculture and the ecosystems of the Barents Sea, the Norwegian Sea, the North Sea and the Norwegian coastal zone. For this reason, about fifty percent of our activities are financed by the Ministry of Fisheries and Coastal Affairs.



[Korean Institute of Ocean Science and Technology](#)



Korea Institute of Ocean Science & Technology (previously KORDI - Korea Ocean Research & Development Institute), is the only comprehensive ocean research organization in Korea and has led the development of marine science and technology within the nation. Since its establishment in 1973, it has played a pivotal role in improving Korea's focus on the development and promotion of marine knowledge, exploitation of marine resources,

Sponsors

and preservation of marine environment, and thus utilize potentials in ocean for the future of Korea.

[Marine Harvest](#)

Marine Harvest is one of the largest seafood companies in the world, and the world's largest producer of Atlantic salmon. The company employs 10 200 people, and is represented in 22 countries. As a result of its ongoing innovation and sustainable development it is the world's largest supplier of farmed Atlantic Salmon - satisfying one fifth of global demand. The company is present and trusted in all major salmon farming regions in the world.



[National Aeronautics and Space Administration \(NASA\)](#)



NASA is a United States government agency responsible for science and technology related to air and space. The Space Age started in 1957 with the launch of the Soviet satellite Sputnik. NASA was created in 1958. The agency was created to oversee U.S. space exploration and aeronautics research.

[Norwegian Research School in Climate Dynamics](#)

ResClim is a national training environment for PhD candidates in climate dynamics providing in-depth knowledge in their specific study field as well as insight into the political and societal impacts of climate change, and the necessary skills to play an active role for prediction, mitigation, and adaption to climatic and environmental change. ResClim is coordinated by the Geophysical Institute, UiB and gathers 10 national partners and 7 international research institutions



[Ocean Carbon & Biogeochemistry \(OCB\)](#)

The US-based OCB program focuses on the ocean's role as a component of the global Earth system, bringing together research in geochemistry, ocean physics, and ecology that inform on and advance our understanding of ocean biogeochemistry. The overall program goals are to promote, plan, and coordinate collaborative, multidisciplinary research opportunities within the U.S. research community and with international partners.



The OCB is supported by the NSF, NASA and NOAA in the USA.

[Research Council of Norway](#)



The Research Council of Norway is a national strategic and funding agency for research activities, and a chief source of

Sponsors

advice on and input into research policy for the Norwegian Government, the central government administration and the overall research community. An important objective is to ensure that Norway adequately invests in research and development (R&D) activity.

[Scientific Committee on Oceanic Research](#)

Formed by the International Council for Science (ICSU) in 1957, SCOR is an interdisciplinary body whose activities promote international cooperation in planning and conducting oceanographic research, and solving methodological and conceptual problems that hinder research. SCOR provides a mechanism to bring together international scientists and has thus been instrumental in the planning and coordination of several large-scale ocean research projects for long-term, complex activities.



[Sea-Bird Electronics, Inc.](#)



Sea-Bird Electronics, WET Labs & Satlantic have combined to form Sea-Bird Scientific. Our focus, to provide reliable data through world-class oceanographic and water quality instruments on integrated platforms enabling the advancement of science worldwide.

Parameters: Temperature, Salinity, Oxygen, pH, Fluorescence, Nutrients, Turbidity, IOPs/AOPs, Irradiance.

[State Key Laboratory of Estuarine and Coastal Research, China](#)

SKLEC is based at the ECNU. It was established by the State Planning Commission of China in 1989 and went into operation in 1995. The research areas in SKLEC are: estuarine evolution and estuarine sediment dynamics, coastal dynamical geomorphology and sediment process, and estuarine and coastal ecology and environment.



[University of Bergen, Norway](#)



The University of Bergen is Norway's second largest university with 14,500 students and 3,200 faculty and staff. It is an urban university who is intricately woven into the geographical, historical and cultural framework of the city. UiB has a high international profile committed to academic and research excellence. It has a long tradition in marine research since its inception and constitutes a northern cornerstone of European marine science. UiB hosted the JGOFS International Project Office—one of the precursors of IMBER— in the period 1996-2003.

Sponsors

[National Geographic](#)

Building on our legacy of supporting exploration worldwide for more than a century, National Geographic has established a regional grant program called Global Exploration Fund, sponsored by the Swedish Postcode Lottery, to support Research, Conservation and Exploration projects led by residents of northern Europe. Research grants must have hypothesis-based scientific research as a primary focus, and are awarded based on potential for new advances in field sciences. Conservation grants are awarded for innovative and applied approaches to conservation issues with potential for global application. Exploration grants support exploration and adventures around the world and are approved by media experts looking for engaging stories and topics suitable for National Geographic media.



Several sessions and workshops are co-sponsored by the following organisations and initiatives:

[Earth System Governance \(ESG\) project](#)



The Earth System Governance Project is the largest social science research network in the area of governance and global environmental change. Our international research programme takes up the challenge of exploring political solutions and novel, more effective governance systems to cope with the current transitions in the biogeochemical systems of our planet. The normative context of our research is sustainable development: We see earth system governance not only as a question of governance effectiveness, but also as a challenge for political legitimacy and social justice.

[Future Ocean Alliance \(FOA\)](#)

The Future Ocean Alliance (FOA) is a nongovernmental, not-for-profit, neutral and independent global entity that creates an alliance of organizations and individuals seeking to address the concerns of governmental and non-governmental researchers and decision-makers. FOA's constituency is dedicated to integrating the best practices of governance processes via its knowledge sharing network. It will seek to do so at the earliest stages of decision-making, and at all scales, to enhance the sustainable development of the ocean from the local to the global levels.

[International Council for the Exploration of the Sea \(ICES\)](#)



The International Council for the Exploration of the Sea (ICES) – is a global intergovernmental organization for enhanced ocean sustainability .

ICES main objective is to increase scientific knowledge of the marine environment and its living resources and to use this knowledge to provide advice to competent authorities. ICES science and advice considers both how human activities affect marine ecosystems and how ecosystems affect human activities. In this way, ICES ensures that best available science is accessible for decision-makers to make informed choices on the sustainable use of the marine environment and ecosystems.

To achieve this objective ICES prioritizes, organizes, delivers and disseminates research needed to fill gaps in marine knowledge related to issues of ecological, political, societal, and economic importance at the pan-Atlantic and global levels.

[North Pacific Marine Science Organization \(PICES\)](#)

PICES is an intergovernmental scientific organisation that aims to promote and coordinate marine research in the northern North Pacific and adjacent seas (particularly northwards of 30°N). It is mandated to advance scientific knowledge about the ocean environment, global weather and climate change, living resources and their ecosystems, and the impacts of human activities. Present members are Canada, People's Republic of China, Japan, Republic of Korea, Russian Federation, and the United States of America.



[Variability and predictability of the ocean-atmosphere system \(CLIVAR\) project](#)



CLIVAR is the World Climate Research Programme (WCRP) project that addresses Climate Variability and Predictability, with a particular focus on the role of ocean-atmosphere interactions in climate. It works closely with WCRP projects on issues such as the role of the land surface, snow and ice and the role of stratospheric processes in climate.

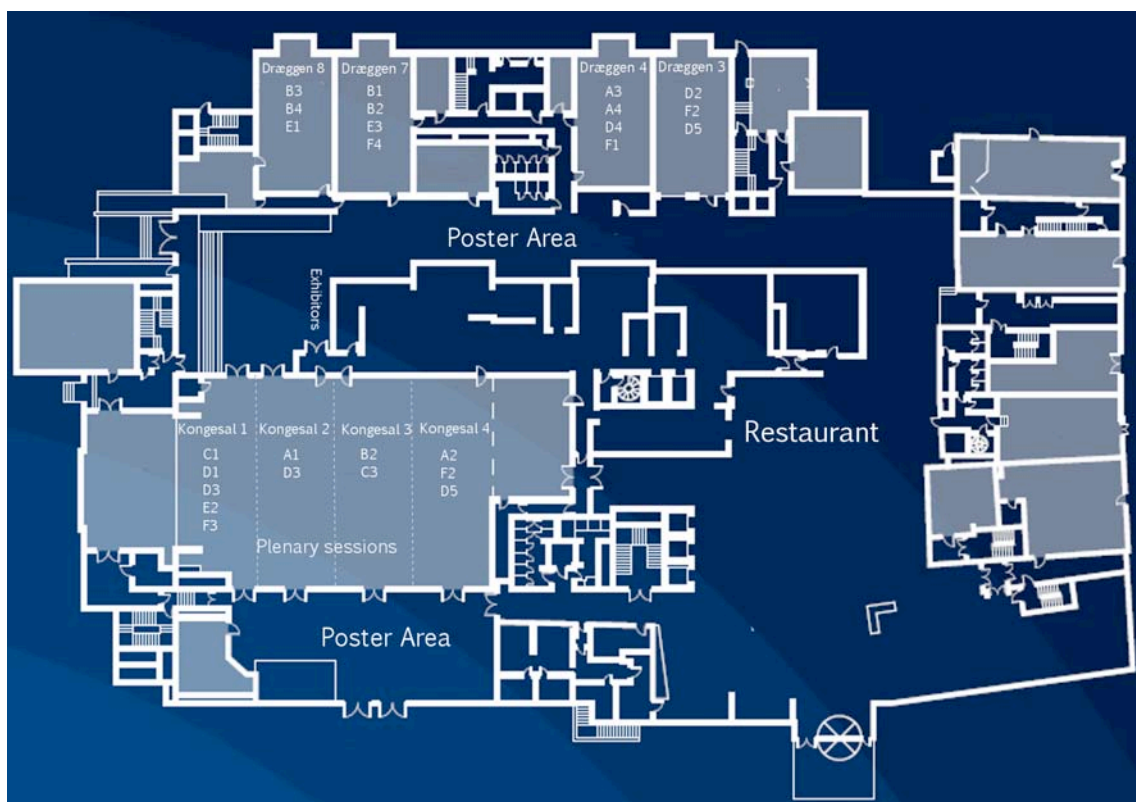
Meeting logistics

Venue

The conference venue is the Radisson Blu Royal Hotel, Bryggen 5, Bergen, Norway



www.radissonblu.no/royalhotell-bergen



Floor plan of the conference venue

Practical information

Registration and information desk

The registration desk will be open during the following hours:

Sunday 22 June: 17:00 - 18:30

Monday 23 June: 07:30 - 09:00

Tuesday 24 June: 08:30 – 09:00

Wednesday 25 June: 08:00 – 09:00

Thursday 26 June: 08:00 - 09:00

You will receive the tickets for the social events in your registration package.

An information desk will be open during conference hours.

Alternatively, please contact: media@kongress.no

Lunch

Lunch is provided each day from 22 - 27 June.

Social events

Ice-breaker

Sunday 22 June 18:30 at Radisson Blu Royal Hotel. Refreshments will be served. One drink is included and then there is a cash bar.

Reception hosted by the Municipality of Bergen

Monday 23 June 18:00 at Håkonshallen, around the corner from the conference venue. See map [here](#). It is also shown on the map in your conference pack. Refreshments will be served.

Conference dinner

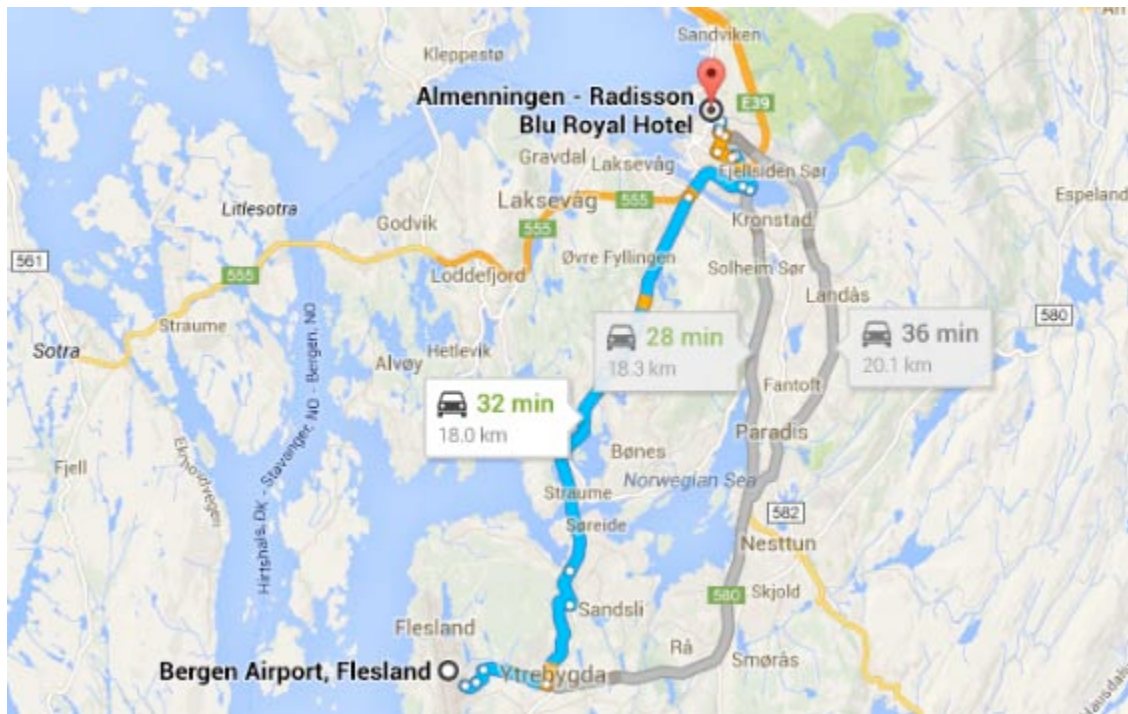
Thursday 26 June 20:00 at Mount Fløyen Restaurant. A ticket for the cable-car is attached to your name tag. Two drinks are included with the dinner and then there is a cash bar.



Practical information

Getting to/from the conference venue and the airport

Flesland airport is 20 kilometres south-west of Bergen city. The trip to the conference venue takes approximately 35 minutes (allow a bit more time during peak times). The airport bus (Flybussen/TIDE) leaves from outside the Radisson Blu. Cost is 90 NOK one way or 160 NOK return. Buy tickets on the bus using cash or credit cards. A taxi to the airport would be about 700 NOK.



Time zone (summer)

UTC/GMT +2

Emergency and useful numbers

Fire: 110; Police: 112; Ambulance: 113

Currency

Exchange rates for the Norwegian Kroner (NOK) are approximately:

100 NOK = 12.0 EUR; 1 EUR = 8.3 NOK

100 NOK = 9.6 GBP; 1 GBP = 10.4 NOK

100 NOK = 16.3 USD; 1 USD = 6.1 NOK

100 NOK = 102 CNY; 1 CNY = 0.98 NOK

To check exchange rates see: www.xe.com/ucc or www.x-rates.com

Practical information

Tourist Information

The Bergen Tourist Office is located at the Torget (Fish Market).

Opening hours: 08:30 -22:00

You can book tours, accommodation, exchange money, etc.

www.visitnorway.com/en



Weather

Bergen is the rainiest city in Europe! It gets about 3 m (that is not a typo!) of rain per year.

Weather forecast, Bergen: [here](#) or [there](#).

Poster information

There are three poster sessions

Monday: Poster session for the Workshops, from 13:00 - 14:00

Tuesday: Poster session 1, from 17:30 – 20:00

Wednesday: Poster session 2, from 17:30 – 20:00

Each poster has been assigned to a particular poster session and a specific display board. Please refer to the workshop or session programmes to see when you are due to present your poster and the poster ID number.

Please ensure that your poster is displayed at least one hour before the poster session starts, and remember to remove it before the end of the morning coffee break the following day.

Any uncollected posters will be disposed of!

Workshops

Sunday 22 June

Workshop 1: Capacity Development for IMBER

Workshop 2: Data Management for IMBER

Workshop 11: Scientific Peer Review and Publication for Young Marine Researchers

Monday 23 June

Workshop 3: A view towards integrated Earth System models: human-natural system interactions in the marine world

Workshop 4: Communities of practice for supporting long-term sustainability of the world's oceans

Workshop 5: Marine regime shifts around the globe: the societal challenges

Workshop 6: Paradigm shift in plankton ecology: the central role of mixotrophic protists in future oceans

Workshop 7: Approaches to predicting fish from physics: strengths, weaknesses and ways forward

Workshop 8: Beyond 'Z': what modellers need and empiricists have to offer to better incorporate higher trophic levels and humans in end-to-end models

Workshop 9: Eastern Indian Ocean upwelling research initiative planning workshop phase 3: physical dynamics and ecosystem responses

Workshop 10: Surface Ocean CO₂ Atlas (SOCAT) Community Event

Workshop 1: Capacity Development for IMBER

Conveners

- **Jing Zhang**
State Key Laboratory of Estuarine and Coastal Research, East China Normal University
Shanghai, China
jzhang@sklec.ecnu.edu.cn
- **Edward Urban**
Scientific Committee on Oceanic Research, University of Delaware
Newark, USA
Ed.Urban@scor-int.org
- **Juliet Hall**
National Institute of Water and Atmospheric Research
Hamilton, New Zealand
j.hall@niwa.co.nz
- **Carina Lange**
Departamento de Oceanografía, Universidad de Concepción
Concepción, Chile
clang@udec.cl
- **John Morrison**
School of Earth & Environmental Sciences, University of Wollongong
Wollongong, Australia
johnm@uow.edu.au

Description of the workshop

The implementation of IMBER at regional and international scales needs capacity development (CD) support at the research project level. Different regions and different IMBER-related projects have different CD needs in order to make their research truly international and sustainable. The proposed workshop will provide opportunities for individual regional projects and task teams to meet in a small forum to discuss what CD activities would be useful to achieve their goals, individually and collectively, within IMBER. At the same time, early-career scientists who plan to attend the IMBER OSC will be invited to discuss what they would find most useful for their personal capacity development in a workshop focused on this topic. The IMBER Capacity Building Task Team will take advantage of the OSC 2014 to assess IMBER's achievements in terms of capacity development so far and to organize some specific future IMBER-related CD activities.

The workshop will primarily be focused around discussion sessions designed to discuss past and current IMBER CD activities and to produce specific plans for future IMBER CD activities. These sessions will provide an opportunity for IMBER projects to present what they view as their CD needs. Before the discussion sessions will be presentations by individuals with experience in ocean science CD (teaching, supervision, mentoring, etc.). Such an approach

Workshop 1: Capacity Development for IMBER

will both showcase IMBER CD activities and what is happening within the IMBER community in relation to capacity development, as well as helping to determine whether any additional efforts are needed, especially in relation to developing countries.

References

Morrison R.J., Zhang J., Urban E.R.Jr., Hall J., Ittekkot V., Avril B., Hu L., Hong G.H., Kidwai S., Lange C.B., Lobanov V., Machiwa J., San Diego-McGlone M.L., Oguz T., Plumley F.G., Yeemin T., Zhu W., Zuo F., 2013. Developing human capital for successful implementation of international marine scientific research projects. *Marine Pollution Bulletin*, 77:11-22. [Article](#)

Urban, E.R. Jr., and Boscolo R., 2013. Using scientific meetings to enhance the development of early career scientists. *Oceanography*, 26(2):164–170. [Article](#)

Workshop Programme

This workshop will cover the following issues through information presentations and open discussions:

- Capacity building through workshops and meetings
- Capacity building through summer schools
- Capacity building through cooperative research and cruise experiences
- Building capacity for project synthesis
- How can the effectiveness of CB be evaluated?
- Should IMBER CB activities change in the second half of the project?

For each topic, the discussion could include how IMBER has used these approaches, how the effectiveness of the approaches can be evaluated, and how they could be used to meet the ultimate goals of IMBER. The input received from the survey will also be used in these discussions.

Workshop 1: Capacity Development for IMBER

Sunday 22 June 2014, 09:00-10:30

Room K2

Time	Presenter	Title
09:00-09:30	Zhang, Jing	Introduction to the workshop
09:30-10:00	Avril, Bernard	Presentation of survey results
10:00-10:30	Hall, Julie	Overview of current IMBER CB techniques

Sunday 22 June 2014, 10:55-12:00

Topic: Existing Approaches – Chair: Julie Hall

Room K2

Time	Presenter	Title
11:00-11:45	All	Discussion about capacity building through workshops and meetings: <ul style="list-style-type: none">• IMBER experience, including OSC and IMBIZOs• Recommendations from Urban and Boscolo, 2013 paper• What more could IMBER do?• Travel grants
11:45-12:30	All	Discussion about capacity building through summer schools: <ul style="list-style-type: none">• IMBER experience

Sunday 22 June 2014, 14:30-16:00

Topic: New Approaches – Chair: Jing Zhang

Room K2

Time	Presenter	Title
14:30-16:00	All	Discussion about: <ul style="list-style-type: none">• Capacity building through cooperative research and cruise experiences:<ul style="list-style-type: none">○ What have other projects and organizations done? e.g., COST Action STMs• Visiting Professorships• Distance Learning• Alumni Network• The role of regional projects and task teams

Sunday 22 June 2014, 16:30-18:00

Topic: The Way Forward – Chair: Ed Urban

Room K2

Time	Presenter	Title
16:30-17:30	All	Discussion about the Way Forward: <ul style="list-style-type: none">• What will be IMBER science needs in the next 10 years that could require different CB activities?• How can the effectiveness of IMBER CB be evaluated?• How can community involvement in IMBER CB be stimulated?
17:30-18:00	Zhang, Jing; Urban, Ed; Hall, Julie	Final Discussion and Conclusion

Workshop 2: Data Management for IMBER

Conveners

- **Cyndy Chandler**
Biological and Chemical Oceanography Data Management Office
Woods Hole Oceanographic Institution, Woods Hole
USA
cchandler@whoi.edu
- **Todd O'Brien**
Marine Ecosystems Division
National Marine Fisheries Service
NOAA, Silver Spring
USA
Todd.OBrien@noaa.gov
- **Alberto Piola**
Departamento Oceanografía, Servicio de Hidrografía Naval
Buenos Aires
Argentina
apiola@hidro.gov.ar

Description of the workshop

Marine scientists need to be aware of the benefits of good data management. Often lack of time, fear of technical jargon, lack of knowledge about the resources that are available, etc., can make it difficult to follow good data management practices. Managing data properly during and after the cruise(s) and after project completion, is good for scientists, their research projects and the larger community, and ensures availability and perpetuity of the data. The legacy of properly managed and preserved data goes on long after the project has been completed and the papers have been published as data are used for different purposes in future applications.

The purpose of this workshop is to enhance awareness of the need to establish data management procedures, to highlight the important advantages arising from following these procedures, and to provide hands-on training on data management and data preservation. These skills will not only benefit IMBER scientists now, but can shape and help to ensure good data management habits in their future research endeavors.

Workshop 2: Data Management for IMBER

Workshop Programme

Oral Presentations

Sunday 22 June 2014, 09:00-10:35

Room K3

Time	Presenter	Title
09:00-09:15	Hofmann, Eileen / Piola, Alberto	Introduction to IMBER and IMBER Data Management Policy
09:15-09:55	O'Brien, Todd	Why does IMBER need Data Management?
09:55-10:35	Chandler, Cynthia	Data Management Essentials: Benefits of following good DM practices and dangers of not doing so

Sunday 22 June 2014, 10:55-12:00

Room K3

Time	Presenter	Title
10:55-11:35	Chandler, Cynthia	Data Management Essentials: Preserving the data for future generations
11:35-12:00	Urban, Edward	Data publication, journals, DOIs

Sunday 22 June 2014, 13:30-15:00

Room K3

Time	Presenter	Title
13:30-14:30	Schlitzer, Reiner	Processing and displaying large data sets for research: the Ocean Data View example
14:30-15:00	Korosov, Anton	Remote sensing data for NRT monitoring of water quality and studying the ocean processes provided by the Nansen Center

Sunday 22 June 2014, 15:30-17:00

Room K3

Time	Presenter	Title
15:30-17:00	All	Discussion and/or hands-on training

Poster Presentation

Tuesday 24 June, 17:30, Poster Session 1

ID	Presenter	Title
W2.P1	Chandler, Cynthia	Data Management in Support of IMBER Research

Data Management Essentials: Benefits of following good DM practices and dangers of not doing so; and preserving the data for future generations

Chandler, C.L.

Data management has always been an essential part of the scientific research process. With cross-disciplinary, large scale research topics becoming more common, management and dissemination of data have become even more critical. There has been a shift recently in expectations for access to research data, with funding agencies expecting data to be made publicly available and colleagues in complementary research domains requiring access to data for complex ecosystem studies. The essential aspects of data management will be covered in a series of modules. We begin with an overview of the basics, and the benefits to research outcomes that result from following good data management practices and the potential dangers of failing to do so. Recommendations will be given for specific types of data including those acquired at sea, from laboratory experiments and from time series sites. Ultimately, the goal is to preserve the data, making them available to future generations and with sufficient documentation to enable re-use in subsequent research initiatives.

Oral Presentation

Data management in support of IMBER research

Chandler, C.L., Groman, R.C., Allison, M.D., Wiebe, P.H., Shepherd, A., Kinkade, D., Rauch, S., Gegg, S.R., Copley, N., Glover, D.M.

Good data management practices are part of the necessary infrastructure that supports successful scientific research. The types of research projects endorsed by the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project involve multi-disciplinary topics and are therefore likely to require integration of data from disparate sources. Such integration can only be done if one can first discover the needed resources, assess 'fitness-for-purpose' and then have access to sufficient metadata (supporting documentation) to enable accurate interpretation of heterogeneous data and re-use of those data beyond the expectations of the original investigators.

Using a US-funded IMBER project as a case study, this presentation describes the essential data management activities that should be addressed by every researcher to facilitate access to resultant data by research colleagues and others. The components include: (1) working with data management professionals to establish a comprehensive data management plan; (2) registering the IMBER-endorsed project at the Global Change Master Directory (GCMD; gcmd.nasa.gov/) portal; (3) ensuring reliable backup of data and supporting documentation; (4) contributing data to a system that supports data discovery, access, display, assessment, integration, and export of the data; (5) submitting final data sets to the appropriate long-term data archive and (6) formal publication of data sets to provide citable references (Digital Object Identifiers) for publishers of the peer-reviewed literature and to encourage proper citation and attribution of data sets in the future. When combined, these elements comprise the full spectrum of the data life cycle; enabling discovery and accurate re-use and ensuring long-term permanent archive of the data that are an important component of a researcher's legacy. Related URL: <http://bco-dmo.org>

Keywords: data management, marine ecosystem, ocean biogeochemistry

Poster presentation

Remote sensing data for NRT monitoring of water quality and studying the ocean processes provided by the Nansen Center

Korosov A. and Johannessen J.

High latitudes are predicted to suffer amplified warming as a result of climate change with associated large effects on water temperature, salinity and quality, ice/snow cover and frequency of weather extreme events (e.g. Drobot et al., 2008; Johannessen, 2008). Changes in the natural properties of fresh and marine waters could favor the growth of harmful algal blooms (Edwards, 2006). An increase in the occurrence and intensity of harmful algal blooms may negatively impact the environment, human health, and the economy for communities across Norway and around the world.

The ongoing monitoring programs relying on water sampling stations or regular measurements by ship-of-opportunity may be discontinuous or suffer from lacunas. The global satellite NRT monitoring systems of water quality (e.g. GLOBCOLOR) do not provide data at spatial resolution high enough for regional monitoring and employ the globally applicable algorithms which may give large errors in coastal waters with regionally specific optical properties. Free access to NRT L2 satellite data provided by ESA or NASA gives opportunity to use optical remote sensing data for regional water quality monitoring but unique features of each satellite sensor (spectral bands, resolution, coverage, file formats, delivery, etc) are challenging to handle.

The Nansen Environmental and Remote Sensing Center (NERSC) has initiated, developed and maintained the Norwegian system for operational monitoring of harmful algae blooms and water quality in the North Sea since 1998 using satellite EO data (<http://HAB.nersc.no>). The system processed optical data from SeaWiFS (1998 – 2002), MERIS (2002 – 2012) and after the ENVISAT decay MODIS (2012 – now) satellite sensors.

The Norwegian Satellite Earth Observation Database for Marine and Polar Research (NORMAP) is developed by joint efforts of NERSC, Norwegian Meteorological Institute and Kongsberg Satellite Services (<http://normap.nersc.no>). The goal is maintaining a repository of Earth Observation data over the high latitude and Arctic regions to facilitate, stimulate and strengthen high quality and original multidisciplinary Earth System research, application, exploitation and education in marine, polar and climate sciences. As such it is complementing and supporting the Norwegian strategy for advancing these science disciplines in the high latitude and Arctic regions.

In the international arena, NORMAP benefits and complements the EU GMES MyOcean project, and other previous GMES downstream services such as AQUAMAR, MONARCH-A, SIDARUS, etc. With the launch of the first Sentinel-1 mission NORMAP will be reinforced by the new data flow from the Copernicus Space Component. NORMAP is also acquiring data from a multitude of other satellites through the unified Copernicus system and will become one of the national thematic information services designed to benefit the environmental monitoring and support effective policy-making.

Keywords: remote sensing, monitoring, time series, ECV

Oral presentation

Why does IMBER need Data Management

O'Brien, T.D.

As an IMBER researcher, you are pouring hours of sweat and expertise into your personal contribution piece of the larger IMBER research puzzle. Your time is precious, too precious to spend on “data management”, right? But what would happen if your computer suddenly died this very second, and all content were lost from it? Would you lose a few hours of work, a few months, or perhaps the entire project? What if you gave your main data spreadsheet to another random IMBER scientist, would they be able to understand your data? (Could they even discern what variable was in each column?) Even if you could “simply explain it to them in five minutes”, imagine having to repeat this exercise again twenty times with twenty other random IMBER scientists. Wouldn't it be so much easier to give them a web link to a data repository?

Your time is precious, but so are your data. Learn how a few minutes of your time “now” can prevent hours of anguish, save you hours of explaining and re-explaining, and can insure that your sweat and expertise will be available now and far into the future.

Oral Presentation

Processing and displaying large data sets for research: The Ocean Data View example

Schlitzer, R.

Ocean Data View (ODV; <http://odv.awi.de/>) is a software package for the interactive exploration, analysis and visualization of oceanographic and other geo-referenced profile, time-series, trajectory or sequence data. ODV has been and continues to be available for Windows, Mac OS X, Linux, and UNIX systems for almost two decades. There are more than 35,000 registered users with about 15 new registrations every day. ODV supports working with local or remote netCDF files. In addition, ODV has its own data format providing dense storage and fast access to large collections of irregularly spaced, variable length observational data. A new version of the ODV collection format has been released recently, now allowing virtually unlimited numbers of metadata and data variables. Both types of variables support numeric values (including data errors and quality flags) or UNICODE strings of arbitrary length. The collection format supports inclusion of ancillary documents (various formats) as well as images, movies and info files, providing access to these documents via simple mouse clicks. The recent release of the GEOTRACES Intermediate Data Product 2014 (<http://www.bodc.ac.uk/geotraces/data/idp2014/>) is an example featuring many of the new capabilities, including seamless integration of cruise reports, descriptions of analytical methods, originator information and references.

Until recently ODV was the only software available to access data in ODV collections. While ODV does provide a broad range of analysis and visualization options, there are still many application-specific use-cases not readily supported. Therefore, a new ODV application programming interface (ODV API) was developed and released to allow users writing their own software for opening ODV data collections and processing the data following user specific needs. This API is available for C++ and Java developers. Versions for other languages, such as Perl, PHP, Python, Tcl, Ruby, C#, R, Octave, GO or D are possible. Usage of the ODV API now allows unprecedented applications of important large datasets, as for instance the World Ocean Atlas 2013 created by the U.S. NODC containing standard depth hydrographic data on global 0.25x0.25 or 1x1° grids, the SOCAT v2.0 collection of more than 10 million $p\text{CO}_2$ data in ocean surface waters as well as the overlying atmosphere, or the Coriolis Ocean Database for ReAnalysis - CORA-3.4 containing more than 6.2 million original temperature and salinity profiles for the 1990 – 2012 time period. These and many other ODV data collections can be found at <http://odv.awi.de/en/data/ocean/>.

Oral Presentation

Data publication, journals, DOIs

Urban, E.

The previous three presentations have discussed the need for good data management for IMBER-related science, the benefits of good data management practices, and the issue of preserving data for future generations. This presentation will discuss options for “publishing” ocean data, which can be part of good data management and can preserve data for future generations. Data publishing involves submitting data to an easily accessible and stable data archive that will assign a persistent identifier to the data submitted. Data publishing is important because it makes data available for re-use by others in the long term in a form that is citable and gives credit to data originators. The presentation will help direct participants to journals for publishing data papers and databases which will assign a DOI to their data, which can be used in subsequent publications in traditional journals.

Oral Presentation

Workshop 11: Scientific Peer Review and Publication for Young Marine Researchers

Conveners

- **Luaine Bandounas**
Journal Publisher Oceanography and Hydrology
Elsevier B.V.
Netherlands
L.Bandounas@elsevier.com
- **Eileen Hofmann**
Editor-in-Chief Journal of Marine Systems
Old Dominion University
Norfolk, Virginia, USA.
hofmann@ccpo.odu.edu
- **Wolfgang Fennel**
Editor-in-Chief Journal of Marine Systems
Universität Rostock
Rostock, Germany
wolfgang.fennel@io-warnemuende.de

Description of the workshop

This workshop for students and early career researchers will aim to provide information on the publishing process and help guide the audience through the process of writing and reviewing papers for international journals.

The following topics will be discussed:

- Understanding scholarly publishing
- Preparing, writing and structuring your article
- Getting to grips with publishing ethics and knowing your rights as an author
- Information on the peer review process
- Steps to follow when reviewing a manuscript

Workshop 11: Scientific Peer Review and Publication

Workshop Programme

Oral Presentations

Sunday 22 June, 13:30-15:30

Room K4

Time	Presenter	Title
13:30-13:45	Bandounas, Luaine / Hofmann, Eileen	Welcome and goals of workshop
13:45-14:15	Bandounas, Luaine	Understanding scholarly publishing
14:15-14:45	Hofmann, Eileen / Fennel, Wolfgang	Preparing, writing and structuring your article
14:45-15:15	Bandounas, Luaine	Getting to grips with publishing ethics and knowing your rights as an author
15:15-15:30	All	Question & Answer (Q&A) open discussion

Sunday 22 June, 16:00-17:30

Room K4

16:00-16:15	Bandounas, Luaine	Information on the peer review process
16:15-17:00	Hofmann, Eileen / Fennel, Wolfgang	Steps to follow when reviewing a manuscript and what makes a useful review
17:00-17:30	All	Q & A open discussion

Workshop 3: A view towards integrated Earth System models: human-natural system interactions in the marine world

Conveners

- **Baris Salihoglu**
Institute of Marine Sciences, Middle East Technical University
İçel-Erdemli, Turkey
baris@ims.metu.edu.tr
- **Raghu Murtugudde**
Dept. of Atmospheric & Oceanic Science, University of Maryland
College Park, USA
ragu@essic.umd.edu
- **Eileen Hofmann**
Center for Coastal Physical Oceanography, Old Dominion University
Norfolk, USA
hofmann@ccpo.odu.edu
- **Laurent Bopp**
Equipe Biogéochimie Marine et Climat, Laboratoire des Sciences du Climat et de l'Environnement (LSCE)
Gif-sur-Yvette, France
Laurent.Bopp@cea.fr
- **Alistair Hobday**
CSIRO
Hobart, Australia
alistair.hobday@csiro.au
- **Elizabeth Fulton**
Marine and Atmospheric Research, Commonwealth Scientific and Industrial Research Organisation
Hobart, Australia
beth.fulton@csiro.au

Description of the workshop

The human dimension is acknowledged as an important component of the marine ecosystem. The explicit inclusion of human interactions as an integral component of marine ecosystems is only beginning, but is already yielding new insights about the functioning of marine ecosystems. To project more accurate future states of marine ecosystems it is essential that human impacts be included with food web and biogeochemical processes. Models that are inclusive of these processes are now beginning to be developed, but considerable effort is still required to allow meaningful interfacing of food web, biogeochemical and socio-economic systems.

Workshop 3: A view towards integrated Earth System models

This workshop will focus on the interface between marine ecosystem biogeochemistry and food webs and socio-economic systems in the framework of natural-human system interactions of relevance for policy and decision making for sustainable management of marine resources. Abstracts that focus on marine food webs, biogeochemistry, modeling and socio-economic systems and coupling through Earth System models are encouraged.

Workshop Programme

Oral Presentations

Monday 23 June 2014, 09:00-10:30

Room K1

Time	Presenter	Title
09:00-09:25		W3+W7+W8 Joint introduction (overview of the three workshops, and a few words from the organisers of the Fish Model Intercomparison Project, FishMIP)
09:30-09:50	Maury, Olivier	Building 21 st century scenarios for global oceanic ecosystems and fisheries
09:50-10:10	Dueri, Sibylle	Projecting the impact of climate change on the global skipjack tuna biomass and consequences for the economic rent of purse seine fisheries
10:10-10:30	Chakraborty, Kunal	Modelling and analysis of ecosystem variability in the Indian Ocean: A coupled 3-D bio-physical ocean general circulation model

Monday 23 June 2014, 11:00-12:00

Room K1

Time	Presenter	Title
11:00-11:20	Keller, David	Modelling the marine impacts of proposed methods to prevent climate change or mitigate its effects
11:20-11:40	Harrison, John	Insights from a new accounting and synthesis of coastal nutrient delivery at the global scale
11:40-12:00	Gipperth, Lena	Actor-oriented societal indicators of man-made eutrophication of marine environments

Monday 23 June 2014, 14:00-15:30

Room K1

Time	Presenter	Title
14:00-14:20	Melaku Canu, Donata	Lessons learnt from clam farming crisis in the Lagoon of Venice. How to adapt to local and global changes?
14:20-14:40	Solidoro, Cosimo	Sustainability, economic value, ecological impact of mussel farms in northern Adriatic Sea under different anthropogenic and climatic scenarios
14:40-15:00	Piñones, Andrea	Antarctic krill (<i>Euphausia superba</i>) early life history at the end of the 21 st century

Workshop 3: A view towards integrated Earth System models

15:00-15:20	Xia, Meng	Understanding nearshore circulation using a coupled Lake Michigan and Grand Haven nearshore wave-current based model
15:20-15:30	All	General discussion

Monday 23 June 2014, 16:00-17:00

Room K1

Time	Presenter	Title
16:00-17:00	All	Preparation of the W3 synthesis. Discussion on the preparation of a potential synthesis paper

Monday 23 June 2014, 17:00-18:30

Room K1

Time	Presenter	Title
17:00-18:30		W3+W7+W8 plenary synthesis (each workshop gives a ~20 minute summary, 30 minutes for open discussion)

Poster Presentations

Monday 23 June, 13:00-14:00, Poster Session for Workshops

ID	Presenter	Title
W3.P1	Piñones, Andrea	Antarctic krill (<i>Euphausia superba</i>) early life history at the end of the 21 st century
W3.P2	Ruiz-Ruiz, Thelma Michelle	Eutrophication in a subtropical lagoon, Sonora, Mexico

Modelling and analysis of ecosystem variability in the Indian Ocean: A coupled 3-D bio-physical ocean general circulation model

Chakraborty K., Paul A., Chatterjee A. and Francis P.A.

This paper describes the results of a coupled 3-D bio-physical model, ocean general circulation model ROMS with an ecosystem model, which has been employed to study biogeochemical variability in the Indian Ocean. The ecosystem model consists of the nitrogen cycle model with parameterized sediment denitrification described by Fennel et al. (2006) and a model of carbonate chemistry following Zeebe and Wolf-Gladrow (2001). The comparison between observed satellite-derived ocean-color images and model simulated chlorophyll demonstrates that the model is successfully capturing the seasonal inter-regional contrasts in sea surface chlorophyll distribution. The model is adequately characterizing two distinct growth periods of phytoplankton, bloom, one in summer during the South West Monsoon (SWM), the other in winter during the North East Monsoon (NEM). The model is successfully producing a persistent occurrence of subsurface chlorophyll maximum in the Arabian Sea and in the Bay of Bengal and is validated with observations from Argo floats deployed in the South-eastern Arabian Sea and in the Northern Bay of Bengal during 2013. The sea surface bloom is caused by the entrainment not only of subsurface nutrients but also due to subsurface chlorophyll maximum. The model effectively simulates the characteristics of oxygen minimum zones (OMZs), which intermediate-depth layers featuring low oxygen saturations, as are observed in the Arabian Sea and in the Bay of Bengal. The existence of a subsurface oxygen maximum zone is attributed to the process of photosynthesis in subsurface chlorophyll maximum zone (Shulenberger and Reid, 1981; Riser and Johnson, 2008).

Keywords: Phytoplankton bloom, subsurface chlorophyll maxima, OMZs

Oral presentation

Projecting the impact of climate change on the global skipjack tuna biomass and consequences for the economic rent of purse seine fisheries

Dueri S., Maury O., Bopp L., Chaboud C. and Guillotreau P.

Skipjack tuna (*Katsuwonus pelamis*) is a tropical tuna commonly found in warm waters (SST over 24° C) in the three oceans. During the last 50 years, commercial pelagic fisheries have increasingly exploited skipjack tuna, catching globally up to 2.2 million tons in recent years. This species represents a high economic value as raw product for the international canning industry. Climate change is expected to affect the bio-physical properties of the oceans, resulting in major changes in temperature, currents, oxygen and primary production. Such changes are likely to impact all the trophic levels of marine ecosystems. The geographical distribution of top predators, such as tropical tuna, their movement, metabolism and physiology (feeding, growth, reproduction, mortality) will be affected by these changes. This is expected to deeply impact fisheries and related activities, which will have to adapt to these new conditions with consequences for their profitability.

We have projected the effects of climate change on the skipjack tuna populations at the global scale, considering both changes in the geographical distribution of habitat and impacts on the physiological rates that will affect abundance, using the APECOSM-E numerical model, previously tested and optimized for the skipjack tuna population of the Indian Ocean. The model is forced with outputs from the IPSL-CM5 Earth System Model for the global warming scenario RCP8.5 and has been coupled with a bio-economic module representing the cost and revenues of purse seine fisheries. The aim of this study is to assess the effect of climate change on the skipjack fisheries considering the redistribution of fishing effort and the impact on both Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY). On the basis of these simulations we evaluate how climate change scenarios are likely to impact the spatial and temporal dynamics of global skipjack tuna populations and their potential effects on fisheries.

Keywords: climate change, scenarios, tuna fishery

Oral presentation

Insights from a new accounting and synthesis of coastal nutrient delivery at the global scale

Harrison J.A., Mogollón J., Bouwman L. and Beusen A.

Although coastal eutrophication and its associated impacts (e.g. increased frequency and severity of hypoxic events, harmful algal blooms, and others) are considered of primary concern and have been documented around the globe, understanding of the human contribution to these problems and a capacity to predict where and when coastal eutrophication and its associated effects will occur are both quite limited. These gaps in understanding are due, in part, to a lack of a clear accounting of nutrient sources to the coastal zone at the global scale. Although efforts have focused specifically on river and atmospheric inputs to the coastal zone, there has not been a systematic effort to use these estimates in concert to calculate total delivery of anthropogenic nutrients to coastal waters. Nor has there been an effort to estimate marine-derived nutrient sources to coastal waters in a spatially explicit manner, at the global scale. Here we will present results from our recent efforts to quantify diverse N and P sources to coastal zones, including atmospheric N deposition, submarine groundwater-derived N, and river-derived, upwelling-derived, and onwelling-derived N and P. At the scale of COSCAT coastal segments (coastal segments chosen so as to represent relatively uniform coastal environments; with 152 COSCAT segments worldwide) our analysis indicates that for N, just over half (51%) of the world's COSCAT regions are dominated by river inputs, followed by upwelling (24%), on-welling (19%), and atmospheric N deposition (7%), with no systems dominated by submarine groundwater inputs. For P, 61%, 10%, and 31% of COSCAT regions are dominated by river inputs, upwelling, and onwelling sources, respectively. We will also present results from our recent effort to use these estimates of total N and P loading to develop predictive models for coastal hypoxia. Best-fit models thus far indicate that temperature, salinity, and N loading can be used as independent variables to explain 59% of the variation in O₂ concentrations and (by logistic regression) 55% of the probability of a system developing hypoxia (defined as O₂<2 mg/L).

Keywords: Hypoxia, eutrophication, nitrogen, phosphorus

Oral presentation

Modelling the marine impacts of proposed methods to prevent climate change or mitigate its effects

Keller D.P., Reith F., Feng E.Y. and Oschlies A.

In attempts to prevent climate change or mitigate its effects humans may decide to either use the ocean to store captured carbon or impact it through geoengineering. Although these are controversial topics, many methods have been proposed and even patented without a proper evaluation of their effectiveness or side effects. We use an Earth system model to investigate how five different climate engineering methods, the direct injection of CO₂ into the deep sea, and the regional addition of alkalizing agents to prevent ocean acidification in coral reef regions will affect the oceans during high CO₂ emission scenario simulations. We demonstrate how these natural-human system interactions can be simulated in an idealized manner with an Earth System model. Our results identify not only the effectiveness and risks of the methods, but also some of the related economic, political, and societal issues that need further study and incorporation into models.

Keywords: Climate change, climate engineering

Oral presentation

Building 21st century scenarios for global oceanic ecosystems and fisheries

Maury O., Arrizabalaga H., Bopp L., Campling L., Anganuzzi A., Cheung W., Goujon M., Guivarch C., Lefort S., Marsac F., Merino G., Monteagudo J.P., Mullon C., Murtugudde R. and Österblom H.

There is an urgent need for clear political strategies aiming at transitioning the world toward sustainability. Long-term visions and goals are needed to design such policies, focus investments and technology development, induce societal changes, and engage actors in society. In this perspective, the development of medium- to long-term scenarios of marine ecosystems and fisheries in the 21st century is a priority. The goal is to understand how key drivers might interact and affect the future, and move beyond simple projections to consider alternative possible futures for the oceans and envision ambitious political evolutions for sustainability.

We present the results of EurOceans, CLIOTOP and MACROES workshop held at IOC-UNESCO to initiate the development of such scenarios for driving socio-ecological models of oceanic systems. One important objective of the scenarios developed is to provide means to compare alternative governance strategies and management options, using available socio-ecological models and conditionally to prescribed trajectories of forcing conditions. In this perspective, the five overarching broad-scope world-scale Shared Socio-economic Pathways (SSPs) developed in the IPCC community were used to provide broad descriptions of radically alternative plausible future worlds and consistent trajectories of forcing factors (energy cost, world population and GDP, etc). The SSPs were downscaled to the oceanic social-ecological system to design five alternative “Oceanic System Pathways” (OSPs): (1) sustainability first; (2) conventional trends; (3) dislocation; (4) global elite and inequality; (5) high tech and market. For each OSP, driving factors of the system were identified in terms of economy (wild fish demand, fishing cost, structure of the market), governance (international cooperation, compliance) and management (objectives, tools). Clear and logically consistent narrative storylines were drawn for the five OSPs.

Future work involves designing and running simulations along each OSP using specifically designed integrated socio-ecological models of oceanic systems and comparing them with specific performance indicators.

Keywords: integrated social-ecological model; SSPs; scenarios

Oral presentation

Lessons learnt from clam farming crisis in the Lagoon of Venice. How to adapt to local and global changes?

Melaku Canu D., Solidoro C., Cossarini G. and Giorgi P.

For several centuries the guiding principle for lagoon management in the Lagoon of Venice (Italy) was to carefully balance anthropogenic impact and ecosystem resilience, in order to preserving ecosystem functioning along with good and services it provided. Manila clam harvesting in the lagoon of Venice started at the beginning of the nineties, after the intentional introduction of this clam species for commercial purposes.

However, in the last decades critical situations arose and there was a clear decrease in the capability of managing this Socio Ecological Systems (SESs), to adapt to new pressures and changes while preserving social structure, economic welfare and ecological status (resilience). Exploitation of marine resources is an example of such criticality. As an example, the introduction of manila clam, about 25 years ago triggered an exponential growth of economic activities related to clams exploitation, but this resource is now declining substantially. Adaptation and mitigation measures to local and global changes need to be supported by information and assessments. With this aim, a downscaling experiment linking a regional atmospheric model to local ecosystem and a target species population dynamic model was conducted to evaluate the effects of IPCC climate change scenarios on a temperate coastal lagoon ecosystem, the lagoon of Venice, along with goods and services provided by this ecosystem. Our results indicate that the changes in water temperature and reduction in plankton productivity caused by the modification of seasonal precipitation patterns will affect habitat suitability for clam growth and aquaculture. Simulations show that aquaculture, will suffer, and they highlight the need for management policies to mitigate the adverse effects of climate change.

Keywords: socio-ecological-system, climate change, adaptation, mitigation, modelling

Oral presentation

Antarctic krill (*Euphausia superba*) early life history at the end of the 21st century

Piñones A. and Fedorov A.V.

Antarctic krill (*Euphausia superba*) is key species and a dominant grazer of the Antarctic marine ecosystem. Krill has an asymmetric circumpolar distribution with the largest krill stocks in the southwest Atlantic sector. In the last four decades the density of Antarctic krill has declined, mainly due to human pressure and the impact of changing environmental conditions. Observations and modelling studies have indicated the importance of understanding the early part of the reproductive cycle (descent-ascent cycle) of Antarctic krill, not all regions around Antarctica support the successful completion of the descent-ascent cycle. The objectives of this study are, to determine the sensitivity Antarctic krill early life history to projected changes of the environmental conditions that result from climate change, and to identify which regions around Antarctica will receive the largest impact. A one-dimensional, temperature-dependent model is implemented to simulate the descent-ascent cycle of Antarctic krill embryos and larvae. The model is forced with 100-year projections (end of the 21st century) of ocean temperature and density fields obtained from the Coupled Model Intercomparison Project (CMIP5), for a high emission scenario (RCP8.5). End of the century sea ice timing and extension were also analysed. The simulations showed that the largest changes of the descent-ascent cycle occur along the eastern Antarctic Peninsula and the Ross Sea. In these regions, simulated hatching depth was sensitive to the changes in sea temperature below 200m. Under future environmental conditions the hatching depth of the embryos shallow by 100-200m. In these regions, simulated embryo hatching depth is sensitive to the change in water temperature below 200m. Embryo hatching depth becomes shallower (~200m) and embryo development time shortens (~30%) because of the warmer water temperature, which accelerates embryo development. We find a high likelihood of krill population decline by the end of this century and discuss the implications for the productivity of the marine food webs of the Ross Sea and the eastern Antarctic Peninsula.

Keywords: Climate change, Antarctic krill, CMIP5

Oral and Poster presentations

Eutrophication in a subtropical lagoon, Sonora, Mexico

Ruiz-Ruiz T.M., Arreola Lizárraga J.A., Enriquez Flores J. and Morque M.L.

Guaymas Bay is a microtidal and well mixed subtropical coastal lagoon. It is located on the State of Sonora, Mexico (27°51-58' N, 110° 49-51' W). The lagoon has an area of ~ 3360 ha and a mean depth of 3 m, and it is adjacent to urban development of the Guaymas city ~120,000 inhab. This study aims to assess the process of eutrophication of this lagoon by the Assessment of Estuarine Tropic Status Model (ASSETS), which has been widely used in eutrophication assessment in estuarine and coastal waters. At 2011-2012 we conducted two sampling of water quality (temperature, salinity, dissolved oxygen, dissolved inorganic nitrogen and chlorophyll a) at 14 sites every fortnight in a representative month of each season of the year. Likewise we determined composition and abundance of macroalgae and phytoplankton through the year. It was observed a seasonal pattern of water temperature to maximum of 33 °C in August and minimum of 14 °C in January; Salinity varies from 31-39 around year; and Dissolved Oxygen to minimum of 4 mg L⁻¹ in August and maximum of 9 mg L⁻¹ in January. The chlorophyll a showed high variation from 0.725 to 8.644 µg l⁻¹, the higher value was in autumn. The DIN lower concentration was in summer (0.582 µM) and the higher concentration in autumn (27.341 µM). The ASSETS model showed that the Overall Human Influence index was moderate, because the bay has a high susceptibility to eutrophication and a nutrient discharge of 86.6 N ton yr⁻¹ from the Guaymas city. The Overall Eutrophic Condition index was high mainly explained by the dominance of opportunistic macroalgae (*Chaetomorpha* spp, *Gracilaria* spp, *Hypnea* spp and *Ulva* spp) and harmful phytoplankton (*Prorocentrum minimum*, *Pseudo-Nitzsia* spp and *Eucampia zoodiacus*) during the annual cycle. The others indicators as dissolved oxygen showed healthy concentrations while chlorophyll a exhibited high variability through the year but with healthy concentrations except in autumn. The Future Outlook Index was unchanged due to the lack of an environmental management program for the water body. In base to the overall grade of the ASSETS Model Guaymas Bay showed eutrophication symptoms and was classified into the Bad environmental condition.

Keywords: Subtropical lagoon, eutrophication, ASSETS model

Poster presentation

Sustainability, economic value, ecological impact of mussel farms in northern Adriatic Sea under different anthropogenic and climatic scenarios

Solidoro C., Del Negro P., Libralato S. and Melaku Canu D.

We assessed ecological impact, economic value and sustainability of mussel farms along the northern Adriatic coast by integrating physical, environmental, ecological, social and economic information.

We monitored on monthly basis mussel growth and several water quality parameters in six sampling sites along the gulf, differing for salinity, hydrodynamic and trophic condition. Potential impacts of farming activity on water quality and upper sediment have been investigated by comparing sediment properties among areas below farms in which mussel production started 5 and 10 years ago, area in which mussel farming stopped 5 years ago, and area in which farming never took place. Finally, laboratory experiments were set up to investigate feeding preference and faeces/pseudofaeces production.

Results were used to calibrate a bioenergetic model representing the mussel physiology and growth in relation to environmental conditions, and the impact of mussel aquaculture on water column. The model was then coupled to an hydrodynamic, a biogeochemical and a food web models for system level computation of mussel potential production, related energetic requirements, and nutrients budget. Information on socio economic aspects of this activity has then been integrated, in order to evaluate ecological footprint, energy balance and social carrying capacity of the activity. Results represent a relevant contribution to coastal zone management, allows for evaluating possible interactions of mussel farms with other uses of the basin and permit the assessment of the ecological role of farming in the ecosystem. Results support the conclusion that mussel farming in this area is a paradigmatic example of sustainable exploitation of a renewable resource. Simulations also indicate the possibility to enlarge this activity without significantly impacting ecosystem status.

Keywords: sustainability, ecological footprint, mussel, Adriatic, Adapt

Oral presentation

Actor-oriented societal indicators of man-made eutrophication of marine environments

Sundblad E.L., Wallin A., Grimvall A., Gipperth L. and Molander S.

The pressure from society on many marine water areas, including large parts of the Baltic Sea, is unsustainable. This calls for changed behaviour by a long range of actors. Initiatives taken to initiate such changes, are today often stated in comprehensive programmes of measures. It is thus necessary that these programmes are based on a good understanding of current state, trends and causal relationships of complex social, economic and natural systems. Especially, it is urgent to identify and characterize societal phenomena contributing to an unsustainable pressure.

In this paper we present a structured method to develop societal indicators that can help identify and follow up programmes of measures to reduce the input of phosphorus and nitrogen to marine environments. This method, which integrates analyses of physical flows with a thorough identification of actors, has the following main components:

1. The BPSIR (Behaviour-Pressure-State-Impact-Response) framework that was recently developed to support the implementation of the Marine Strategic Framework Directive.
2. A generic model of the flow of substances and goods, which presents physical flows in a standardized way on any scale from flows of specific products to flows aggregated over whole sectors or societies.
3. Analyses of influence that describe how actors influence other actors.

The BPSIR framework emphasizes the importance of both direct actors operating on the interphase between biosphere and technosphere, and indirect actors influencing the direct actors. The generic model draws attention to important actors along the entire supply chain from raw materials or producer goods to production, distribution, consumption and waste management. Analyses of influence help identify actors operating with information flows.

A case study of the flow of phosphorous and nitrogen through the agriculture and food sectors in the Swedish society demonstrated that important groups of actors and their behaviour could be identified by analyzing aggregated substance flows, whereas specific actors were more efficiently identified by analyzing product chains. As an example of this, the product chain of beef was analyzed.

When strong links between actors and physical flows of nitrogen and phosphorus have been established, the magnitude of the physical can serve as a societal indicator. Other societal indicators can be based on surveys of the behaviour of key actors. Regardless of the type of societal indicators emanating from our method, further work is needed to ensure feasibility of data collection and acceptance of proposed indicators.

Keywords: Societal indicators, actors, marine strategy framework directive

Oral presentation

Understanding nearshore circulation using a coupled Lake Michigan and Grand Haven nearshore wave-current based model

Xia M., Schwab D.J. and Mao, M.

It is widely known that nearshore and coastal water is the important region in Great Lakes and ocean. Because of the complex geometry of coastline, a high-resolution unstructured grid model is required for the nearshore region, however it would be time-consuming if applying a high-resolution model outside the interesting area or in the whole lake. Unlike the coastal ocean, the lake circulation significantly influences the nearshore and coastal circulation. Additional local phenomenaes (e.g., wave) also need be included in the nearshore or coastal model and it requires additional time to simulate these processes using the large lake scale model. So an accurate couple lake and nearshore model is critical for the nearshore dynamics at the lakes. The nesting system between the relatively low-resolution Lake Michigan model and Grand Haven nearshore high-resolution one using Finite Volume Coastal Ocean Model (FVCOM) demonstrated the successful understanding of the nearshore dynamics. It was concluded the nesting is important to sustain the long term hydrodynamics simulation even the wind is a key to the nearshore dynamics.

Based on the Lake Michigan and Grand Haven coupled model system, the effect of wave to the nearshore circulation is further investigated. Forced by the lake model, the Grand Haven nearshore circulation model is coupled with wave model or FVCOM-SWAVE. The effect of waves on nearshore circulation and velocity fluctuations were simulated and calibrated at the nearshore region with the help of the observational ADCP measurement data. It depicted that currents are influenced by surface waves primarily by way of surface wind stress, radiation stress, and bottom stress. It was concluded that among the processes that wave effects present to the system, radiation stress and current-wave interaction are more important than wave-induced bottom stress. In additional, the individual and coupled effects of the river discharge, waves, ambient flow and atmospheric winds on the nearshore circulation are discussed and summarized: river discharge and ambient flow have little influence on the nearshore circulation, while they interplay with the wave forcing at the coasts.

Keywords: Michigan, wave, current, FVCOM

Oral presentation

Workshop 4: Communities of practice for supporting long-term sustainability of the world's oceans

Conveners

- **Oran Young**
Bren School of Environmental Science and Management, University of California
Santa Barbara, USA
young@bren.ucsb.edu; oran.young@gmail.com
- **Luis Valdes**
Intergovernmental Oceanographic Commission, United Nations Organization for
Education, Science and Culture
Paris, France
jl.valdes@unesco.org
- **Isabel Torres de Noronha**
Future Ocean Alliance
Lisboa, Portugal
itnoronha@future-ocean-alliance.com
- **David Vousden**
Agulhas and Somali Current Large Marine Ecosystems Project
Grahamstown, South Africa
david.vousden@asclme.org
- **Ruben Zondervan**
Earth System Governance International Project Office, Lund University
Lund, Sweden
ruben.zondervan@esg.lu.se
- **Robin Mahon**
Centre For Resource Management and Environmental Studies, Univ. of West Indies
St Michael, Barbados
Robin.Mahon@cavehill.uwi.edu; rmahon@caribsurf.com
- **Marion Glaser**
Dept. Social Sciences, Leibniz Centre for Tropical Marine Ecology
Bremen, Germany
marion.glaser@zmt-bremen.de
- **Suzanne Lawrence**
Consultant, USA
suzanne@suzannelawrence.net
- **Peter Fox**
Department of Earth & Environmental Sciences, Rensselaer Polytechnic Institute
Troy, USA
pfox@cs.rpi.edu

- **Leopoldo Cavaleri Gerhardinger**
Centre for Environmental Studies, University of Campinas
São Paulo, Brazil
leocavaleri@gmail.com

Description of the workshop

Global ocean governance needs to address the sustainability challenges of the 21st century. This requires linking natural and social science knowledge with that of decision-makers and ocean users in business and civil society in order to deliver science and knowledge to the governance process for more timely and effective adaptive management. There is thus a large number of individual and organisational actors engaged in the fields of knowledge generation and governance and management relating to the global oceans. Members of the recently initiated “Future Ocean Alliance” understand effective ocean governance as requiring an operational global social network which effectively links ocean governance actors across sectors, issues, regions, disciplines and interest groups. Our session will also invite the presentation of case examples on how to generate connectivity in ocean governance at various levels of the Earth system from the regional to the global (e.g., Agulhas and Somali Current Large Marine Ecosystems Project, Western Indian Ocean Sustainable Ecosystem Alliance; Caribbean LME project; LOICZ). The session will be accompanied by a world café type of participatory exercise in which all will be invited to engage in a digitally supported systematic mapping of ocean governance actors and their linkages. The developing global network will be made visually available during the course of the conference. A final discussion panel will examine first results at the end of the conference. This will set the scene for building a global alliance for ocean governance and also for producing a published analysis of the state of world ocean governance today.

Workshop 4: Communities of practice

Workshop Programme

Oral Presentations

Monday, 23 June 2014

Part 1, 09:00-10:30

Chair: Isabel Torres de Noronha

Room D3

Time	Presenter	Title
09:00-09:15	Young, Oran	Knowledge, action, and the future of the oceans
09:15-09:30	Mahon, Robin	Is there an emerging structure among ocean governance arrangements for the open ocean?
09:30-09:45	Fox, Peter	Informatics approaches as basis for integrating science and governance across scales in complex networks of large marine ecosystems.
09:45-10:00	Torres de Noronha, Isabel	The Future Ocean Alliance: options and visions
10:00-10:30	All	Discussion

Part 2, 11:00-12:30

Topic: Setting the Stage for Netmapping of Global Ocean Governance

Room D3

Time	Presenter	Title
11:00-11:30	Glaser, Marion	Social network analysis for global ocean governance
11:30-12:30	Hosts: Marion Glaser, Philipp Gorris, Eike Holzkämper	Netmapping of global ocean governance: multi-stage world café

Part 3, 14:00-16:00

Topic: Netmapping of Global Ocean Governance: Multi-stage World Café

Room D3

Time	Presenter	Title
14:00-16:00	Hosts: Marion Glaser, Philipp Gorris, Eike Holzkämper	Netmapping of global ocean governance: multi-stage world café

Part 4, 16:30-17:30

Roundtable & Open Discussion

Room D3

Time	Presenter	Title
16:30-17:30	Moderator: Ruben Zondervan	Roundtable & open discussion

Informatics approaches as basis for integrating science and governance across scales in complex networks of large marine ecosystems.

Fox, P.

The many scales encountered in assessing and managing large marine ecosystems (LMEs) presents a level of diversity and heterogeneity, or complexity, presents a challenge to those diverse stakeholders and contributors (spanning the spectrum from the general public through decision makers and on to scientists). In turn, the knowledge network of LMEs is necessarily complex, i.e. there is not one overall 'categorization, or typing' of LMEs. The clear and overarching goal is to sustainable governance (broadly cast) of LMEs based on the best science; data and information. Forms of vertical integration will be presented in this contribution, as will the ways in which stakeholder identities and roles are preserved and respected. The basis for maximizing potential for success lies in the application of modern informatics theory and practice, including use cases, information modeling, and scalable multi-modal network design. The presentation will outline what the resulting virtual organization may look like, and conclude with some tactical steps now that the immediacy of ecosystem based management of the oceans is apparent world wide.

Keywords: networks; informatics; multi-stakeholder; ecosystems; ocean governance

Oral presentation

Social Network Analysis for Global Ocean Governance

Glaser, M., Gorris, P., Holzkämper, E.

Understanding social networks and their properties is key in the search for why and how human efforts to manage the natural environment succeed or fail. Oceans are governed through a complex web of formal and informal relations. There is little knowledge on global ocean governance though. If understood as a set of interrelated social networks, ocean governance expresses the values, policies, laws and institutions that guide how marine issues are addressed. Ocean governance actors from the public and private sectors and from civil society engage in various social behaviors such as providing support, collaborating and forming coalitions. Science and other forms of knowledge play a potentially influential role in diverse governance arenas. Any governance system can be assessed through a set of critical structuring variables which influence each other. The presentation outlines some conceptual and methodological principles of social network analysis and introduces avenues for the collective exploration of current global ocean governance which workshop participants may engage with.

Oral presentation

Is there an emerging structure among ocean governance arrangements for the open ocean?

Mahon R., Fanning L. and Gjerde K.M.

The plethora of governance arrangements relevant to the open ocean is often said to be fragmented and uncoordinated. An analysis of 98 global and regional arrangements for open ocean governance of fisheries, pollution, biodiversity and climate change indicates an emerging overall structure. Broadly, the picture is one of two sets of networks: (1) weakly interconnected global-to-regional issue-based networks addressing the above issues, and (2) regional intersectoral complexes/networks which appear, in all but a few instances, uncoordinated.

The global-to-regional issue-based networks are organised around global agreements and facilitated primarily by UN agencies. At the regional level, there appear to be several regions in the world where arrangements pertaining to open ocean issues (and often to ocean issues in general) overlap and interact. These regional clusters of arrangements appear to provide potential arenas for place-based implementation of global arrangements. Fifteen such regional clusters have been identified and reflect a diversity of regional level approaches to intersectoral integration and ecosystem-based management, ranging from relatively well integrated, as in the case of the Pacific Islands Region and Antarctic, to having minimal integration, as seen in several regions.

The spatial coherence of these regional complexes is also highly variable. Frequently, the regional arrangements addressing the issues of concern were developed without reference to other regional arrangements operating in the same area. Some arrangements, notably those involving RFMOs for highly migratory species (HMS), appear in several complexes. For example, ICCAT is included in each of the five Atlantic Ocean complexes. Few of the complexes were found to have clearly identifiable overarching mechanisms for policy development and coordination.

Together these two sets of networks – ‘global-to-regional issue-based’ and ‘regional complexes’ – may provide a useful way of structuring what is usually perceived as a fragmented, unstructured system of ocean governance arrangements. This structure may provide a way for stakeholders to engage with the entire system or specific parts of it by facilitating identification of the kinds of interventions needed to strengthen connectivity within and between networks and where these interventions might be most needed.

Keywords: governance, networks, MEAs, High Seas, ABNJ

Oral presentation

The Future Ocean Alliance: Options and Visions

Torres de Noronha I.

The Future Ocean Alliance (FOA) aims to build a single ocean community, connected across scales and disciplines, that engages proactively in ecosystem based management by producing and integrating knowledge into governance processes to ensure a healthy and sustainable ocean. FOA will be doing with support of innovative informatics to build a global community – a global ocean knowledge network- able to address emerging ocean governance issues promptly, efficiently, and fairly.

FOA is an association that brings into an alliance organizations and individuals dedicated to integrating knowledge and governance processes at early stages of decision-making at all scales to enhance ocean sustainability in the face of cascading changes that are threatening the health of the world's marine systems from the local level to the global level. To this end, FOA will act as a connector and catalyst for collaboration among diverse communities of practice with strong ocean interests. These collaborations span at all spatial scales from local, national, regional, to global. FOA's constituency includes all ocean actors ranging from individuals, researchers, and decision-makers ranging from policy, public administration, research managers, businesses, and civil society groups. As such, FOA will promote a network of networks, acting across and within disciplinary, organizational, geographic and international boundaries, to:

- Deliver an ocean research agenda focused on knowledge for sustainable development of the ocean
- Develop a coordinated global knowledge network for the ocean, inclusive of the multiple scales and levels
- Promote sharing and access to curated knowledge and expertise
- Analyze and disseminate the results of research pertaining to questions into ongoing governance initiatives;
- Launch concerted efforts to elicit and frame cutting-edge questions that will serve to deliver solutions with all those concerned with sustainable management of marine ecosystems.

At the Rio+20 Conference (2012), the ocean community acknowledged the need to concentrate efforts to enhance ocean and coastal management and governance, including capacity development, and the need to address emerging issues. Rio+20 delivered various global coordinating initiatives addressing ocean policy. However, none addressed the needs for coordinated knowledge, management and governance.

The need for a coordinated mechanism to enhance ocean governance, management and knowledge has been acknowledged and discussed in numerous other fora over the past 20 years (Rio92). Since 2011, members of the research and decision-making communities have been meeting at international venues to consider responses to this challenge. The aftermath of Rio+20 culminated with the set up of FOA in Lisbon, aiming to provide such coordination engine and to help pushing the formal system toward the necessary adjustments.

Oral presentation

Knowledge, Action, and the Future of the Oceans

Young O.R.

What roles do knowledge and knowledge systems play in making, implementing and evaluating decisions about issues of ocean governance. Using the concept of the policy cycle, this presentation argues that (i) the contributions of knowledge differ from one stage of the cycle to another and (ii) the determinants of the effectiveness of these contributions are specific to each of the stages of the cycle. We tend to direct attention to the role of science at the stage of making unique choices (e.g. whether to go forward with the Revised Management Procedure in the International Whaling Commission, whether to establish MPAs in the Ross Sea under the Convention on the Conservation of Antarctic Marine Living Resources, whether to ban heavy fuel oils in the Arctic under the terms of the Polar Code developed by the International Maritime Organization). But this is a process in which other considerations regularly play a powerful role and the contributions of knowledge are particularly circumscribed. By contrast, the roles that knowledge plays in other stages of the policy cycle receive far less attention. We ought to devote more thought to the factors that determine the effectiveness of knowledge in shaping policy agendas and in organizing the implementation of choices rather than bemoaning the limited roles of knowledge and knowledge systems at the stage of making unique choices.

Keywords: policy cycle, agenda formation, choice, implementation

Oral presentation

Workshop 5: Marine regime shifts around the globe: the societal challenges

Conveners

- **Alessandra Conversi**
Sir Alister Hardy Foundation for Ocean Science
Plymouth, UK
alecon@sahfos.ac.uk; a.conversi@ismar.cnr.it
- **Christian Möllmann**
Institute for Hydrobiology and Fisheries Science, University of Hamburg
Hamburg, Germany
christian.moellmann@uni-hamburg.de
- **Carl Folke**
Beijer Institute of Ecological Economics, Royal Swedish Academy of Sciences
Stockholm, Sweden
carl.folke@beijer.kva.se
- **Martin Edwards**
Sir Alister Hardy Foundation for Ocean Science
Plymouth, UK
maed@sahfos.ac.uk
- **Sebastian Villasante**
Department of Applied Economics, University of Santiago de Compostela
Santiago de Compostela, Spain.
s.villasante.arg@gmail.com; sebastian.villasante@usc.es

Description of the workshop

Regime shifts are phenomena during which the entire ecosystem may shift from one stable state to another. In the oceanic realm, regime shifts have been reported in all basins, and are expected to increase in occurrence, because of climate change, and of human impacts in the oceans, which lead to a decline in ecosystem resilience. They have been reported also in limnology, estuarine, and terrestrial ecology. The interest of the scientific community on the field of regime shifts is shown by the large and growing number of articles on this topic in the recent years.

These phenomena do not just interest scientists, but managers as well, since such shifts may carry unforeseen changes in ecosystem services (e.g., collapses of fisheries, habitat reduction), which can have substantial impacts on human economies and societies. Because of their abruptness and unpredictability, regime shifts are difficult to anticipate and costly to reverse, or mitigate, if at all possible.

The aim of this IMBER session is to focus on the social-ecological impacts of regime shifts, linking the effects of global change and anthropogenic impacts on marine systems with societal impacts and possible futures. The overall objective is to build on this scientific

Workshop 5: Marine regime shifts

understanding in order to explore the best strategies to mitigate or adapt to regime shifts, and to evaluate the range of possible marine policy actions.

To achieve this objective, this session will bring together experts from both natural and social/economics sciences in order to discuss how to predict and mitigate the effects of ecological marine regime shifts on human societies; to propose possible future scenarios; to evaluate policy and management options; and to identify the key challenges in this area.

Workshop Programme

Oral Presentations

Monday 23 June 2014, 09:00-10.30

Chair: Martin Edwards

Room K2

Time	Presenter	Title
09:00-09:10	Conversi, Alessandra	Introduction to workshop
09:10-09:40	Certain, Gregoire	Are "Early Warning Signals" useful for the management of large marine ecosystems ?
09:40-10:10	Buttay, Lucie	Shift in seasonal amplitude and synchronicity of zooplankton in the northwest Iberian shelf driven by meteo-hydrographic forcing
10:10-10-30	All	Discussion

Monday 23 June 2014, 11.00-12.30

Chair: Christian Möllmann

Room K2

Time	Presenter	Title
11.00-11:30	Van Putten, Ingrid	Empirical evidence for different cognitive effects in explaining the attribution of marine range shifts to climate change
11:30-12:00	Conversi, Alessandra	Ecological marine regime shifts around the world: analogies, impacts, and challenges
12:00-12:30	All	Discussion

Workshop 5: Marine regime shifts

Monday 23 June 2014, 14.30-16.00

Chair: Alessandra Conversi

Room K2

Time	Presenter	Title
14.30-15.00	Blenckner, Thorsten	Regime shifts and multiple drivers in the Black Sea and Baltic- lessons from their recent history
15.00-15:30	Möllmann, Christian	Socio-economic implications of the Baltic Sea regime shift and feedbacks to the ecosystem
15:30-16:00	Montero-Serra, Ignasi	Warming shelf seas drive the tropicalization of European pelagic fish communities

Monday 23 June 2014, 16.30-18.00

Chair: Alessandra Conversi

Room K2

Time	Presenter	Title
16.30-18.00	Panel	Discussion

Poster Presentations

Monday 23 June 2014, 13:00-14:00, Poster Session for Workshops

ID	Presenter	Title
W5.P1	Austin, Peter	Performance of marine regime shift detection methods.
W5.P2	Hall, Julie	Comparison of Continuous Plankton Recorder zooplankton data between Ross Sea, and East Antarctic regions of the Southern Ocean
W5.P3	Saitoh, Sei-Ichi	Potential habitat patterns of neon flying squid in central North Pacific in response to high-frequency climate oscillations

Performance of marine regime shift detection methods.

Austin, P. and Conversi A.

Marine regime shifts are abrupt changes usually involving several trophic levels. Evidence for this is already available in the form of kelp forest degradation to urchin barrens, coral reefs to macro-algae reefs, and shifts in the dominant species in pelagic and nekton communities. Regime shifts drivers are still under debate, and several overlying factors are being studied, including climate change, global warming, predator/ prey abundance and anthropogenic activities. The after-shift states may not necessarily have the same ecosystem services as previous ones and therefore can be detrimental for both social-economic and ecological means. Correct detection of regime shifts is important; however current statistical detection methods such as CUSUM and STARS have inherent advantages and disadvantages. For example, the widely used STARS - Sequential t-test algorithm for analysing regime shifts developed by Sergei Rodionov (Rodionov and Overland, 2005), has serious limitations. For example, it is not robust (the year of the regime shift can change if one changes the length of the series), it often inserts spurious regime shifts at the end of the time-series, and using raw data vs. pre-whitened data can often produce different magnitudes or results. While CUSUM- Cumulative sums of scaled deviations, requires adequate time series length, before and after the regime shift, therefore rendering some data-sets incompatible for its use. In our work we study the performance of these methods and others identified in the literature, on both simulated and real time series in the North Sea (climate patterns, temperature, copepod populations abundance). We hope to find the most robust and accurate method of detection, and potentially improving it for wider use. The results of this research could impact the scientific community, whom are researching regime shifts globally. Especially in the Southern Hemisphere where adequate data sets are few and far between, using a more robust statistical method could increase the confidence of regime shifts in these data sets. Furthermore, the results could also provide socio- economic impacts, helping policy makers understanding the potential of regime shift in our oceans, and preparing in protecting ecosystems.

Keywords: Marine Regime Shift detection

Poster presentation

Regime shifts and multiple drivers in the Black Sea and Baltic– lessons from their recent history

Blenckner T., Daskalov G. and Stenseth N.C.

The Black Sea and the Baltic Sea are two European lake-like marine systems where regime shifts have occurred. Both ecosystems show similar features and hold comparable long-term records for the main food web components and external pressures. Here we analyse Black Sea and Baltic Sea multi-trophic time series applying the same statistical tool, which allowed us to characterize tipping points and quantify the main dynamics in each regime. In both systems multiple drivers caused a regime shift. We test the resilience of these ecological mechanisms by simulating multiple driver scenarios. We found that under certain environmental conditions a regime shift occur but depending on different conditions suggesting that the observed changes resulted from a combination of heavy fishing and unfavourable conditions. Through the outlook of one single methodology applied to two different but comparable systems we discuss the obstacles we may find if we are to promote a more desirable state and management measures considering synergistic effects of fishing and future climate change.

Keywords: regime shifts, trophic control, food webs

Oral presentation

Shift in seasonal amplitude and synchronicity of zooplankton in the northwest Iberian shelf driven by meteo-hydrographic forcing

Buttay L., Cazelles B., González Quirós R., Miranda A. and Nogueira E.

We have investigated zooplankton temporal dynamics in the northwest Iberian shelf, a temperate ecosystem subject to coastal upwelling-downwelling processes. To this aim, we have applied wavelet analysis, a methodology able to cope with non-stationary dynamics, to monthly time series of zooplankton abundance and biomass acquired between 1995 and 2011 at two locations over the shelf and to environmental variables known to affect functioning of this ecosystem (wind regime, Ekman transport and river outflows).

The seasonal signal of total zooplankton abundance and of the main taxonomic groups showed an abrupt increase in amplitude around 2001 that persisted until the end of the series in 2011. Concurrent with the change in amplitude, there was a synchronization of the seasonal cycle of abundance among taxonomic groups (e.g. copepods, larvaceans, chaetognats...) and copepod species, which persisted for several years although it decreased at the end of the series.

Between 2001 and 2004, significant changes in wind regime patterns, linked to variability of the North Atlantic Oscillation, were observed: westerly winds became predominant, river outflow increased and offshore Ekman transport decreased. This meteo-climatic configuration favors retention mechanisms over across-shelf exchange processes due to the reinforcement of the western Iberian buoyant plume (WIBP) and the prevalence of downwelling. We hypothesized that the observed changes in zooplankton dynamics are governed by the amplification of the seasonal signal of these environmental drivers causing enhancement of the retention phenomena.

Keywords: Zooplankton time-series, wavelets, synchronicity, Iberian Shelf

Oral presentation

Are “Early Warning Signals” useful for the management of large marine ecosystems ?

Certain, G. and Planque B.

Investigations on the nature and causes of temporal variations in ecological systems play a central role in ecology. In recent decades, a particular form of variability termed “regime shifts” has attracted the attention of empirical and theoretical ecologists alike. While theoretical ecologists have linked regime shifts to the theory of mathematical catastrophes, empirical ecologists have generally adopted a much broader definition that encompasses many kinds of sudden / high amplitude / infrequent events, but is not necessarily associated with specific mathematical models. In a management perspective, regime shifts pose a real challenge because they open for the possibility of extreme events to happen with little advance warning. The possibility of predicting regime shifts in advance could help managers to adapt management schemes in due time. This idea is the rationale for the development of statistical tools termed ‘early warning signals’ (EWS) and their application to a growing number of ecological systems. EWS can be highly seducing from a manager point of view. They are simple properties that change in characteristic ways prior to a critical transition. Their definition is based on the theory of mathematical catastrophes, they can be empirically computed from any time series and they are today available online (www.early-warning-signals.org). In this context, worldwide initiatives aiming at designing EWS for fisheries management can easily multiplies.

We examined the theoretical foundations and empirical applications of EWS in ecological systems. For this purpose, we carried out an extensive literature review, using as a starting point the recent special issue of *Theoretical Ecology* (August 2013) on Early Warning Signals. We paid particular attention to the spatial and-temporal dimensions of the biological systems studied, the sampling and monitoring methodologies, the system complexity, and the adequacy between the theory underpinning the chosen EWS and their application to a specific case study. In the light of these results, we evaluate the applicability of EWS tools for large marine ecosystems, given their specific monitoring and modelling characteristics and provide recommendations regarding the use of EWS for fisheries management.

Keywords: Early Warning Signals, Large Marine Ecosystems

Oral presentation

Ecological marine regime shifts around the world: analogies, impacts, and challenges

Conversi A.

Regime shifts are abrupt changes in ecosystems structure and function, and have been reported worldwide in the marine realm. Such shifts can carry significant socio-economical impacts, for example when they involve fisheries collapses or coral reef degradations.

The importance and actuality of the theme is shown by the large increase in the studies relating to marine regimes shifts, which have increased 4-fold in the last 10 years. Major questions are however still unsolved, and cover theory (alternate, stable states? Stochastic oscillations?), ecology (what are the main drivers, do they act synergistically? is there a world-wide synchronicity in marine regime shifts?), applications (can we predict regime shifts?), and marine policy (can we manage regime shifts?).

This presentation will briefly review some of these questions and introduce the work prepared on this topic by more than 60 authors from around the world, for a special issue on *Philosophical Transaction B* (2014): *Marine regime shifts around the globe: theory, drivers, and impacts*.

Keywords: regime shifts; oceanography; climate impacts; policy;

Oral presentation

Socio-economic implications of the Baltic Sea regime shift and feedbacks to the ecosystem

Möllmann C., Vos, R., Quaas M. and Blenckner T.

Regimes in any complex system are stabilized and destabilized (up to eventual regime changes) by positive and negative feedbacks between system components. While feedbacks within ecological systems are increasingly understood, feedbacks between ecological and related socio-economic systems are not sufficiently explored. Ecosystem regime shifts are ubiquitous in the marine environment and the Baltic Sea regime is a key example. During the late 1980s/early 1990s physical oceanographic changes and overfishing have resulted in a large-scale reorganization of ecosystem structure and function. Characteristic for the regime shift is the collapse of the Eastern Baltic cod (*Gadus morhua callarias*) which forms the commercially most important fish stock of the Baltic Sea. Hence, the regime shift had important socio-economic consequences for the Baltic Sea fisheries and the related communities. Recently, European Union management of the cod stock has resulted in a strong reduction in fishing pressure leading to signs of recovery. Here we explore the potential feedbacks between the ecosystem, the socio-economic system and fisheries management. We first evaluate the socio-economic consequences of the regime shift in terms of total profits, distribution of profits and fishing effort (as an index of employment). We then investigate the relationship between socio-economic conditions and fisheries management performance. Eventually we attempt to characterize feedbacks between the ecosystem, the socio-economic system and fisheries management that may have (i) amplified the collapse of the cod stock, and (ii) caused the recent reduction in fishing pressure.

Keywords: Baltic Sea, Feedbacks, Regime shifts, Socio-economy

Oral presentation

Warming shelf seas drive the tropicalization of European pelagic fish communities

Montero Serra, I., Edwards M. and Genner M.J.

In European seas pelagic fishes are among the most ecologically and economically important fish species in marine environment. In principle these species have potential to demonstrate rapid distributional shifts to climatic variability due to their high adult motility, planktonic larval stages, and low dependence on benthic habitat for food or shelter during their life histories. We collated spatially widespread fisheries-independent data from surveys conducted in European waters from a total of 57,870 trawls between 1965 and 2012 and analysed changes in the distribution and frequency of occurrence of the six most common species. We observed large changes in both of these parameters in all species, and in particular a strong tropicalization of the North Sea and Baltic Sea assemblages. These areas have shifted from cold-water assemblages typically characterised by Atlantic herring and European sprat from the 1960s to 1980s, to warmer-water assemblages including Atlantic mackerel, Atlantic horse mackerel, European pilchard and European anchovy from the 1990s onwards. Models indicated the primary driver of change in these species has been sea surface temperatures in all cases. Our analyses highlight how pelagic marine species can show strong distributional responses to climate change, implying that the dependence of species on spatially-fixed habitat will be important for assessing the distributions of future fisheries.

Keywords: pelagic fish, climate change, North Atlantic

Oral presentation

Comparison of Continuous Plankton Recorder zooplankton data between Ross Sea, and East Antarctic regions of the Southern Ocean

Robinson K.V., Pinkerton M.H., [Hall J.](#) and Hosie G.W.

Zooplankton abundances and communities were compared between the Ross Sea region, using the NZ-CPR data, and the East Antarctic region, using the Australian and Japanese CPR data. Latitudinal patterns in species composition were similar between the RS and EA regions and with previous publications. However, CPR data from the Ross Sea showed that zooplankton abundance in the Ross Sea region was substantially higher than in the East Antarctic region, and higher than predicted from models built from previously-collected CPR data. Chlorophyll-a concentrations are also higher in the Ross Sea region than in the East Antarctic region (as shown in both CPR colour index and ocean colour satellite data). There is an indication that variability in zooplankton abundance in the Ross Sea region is higher than in the East Antarctic region. Especially high zooplankton abundances in the Ross Sea region occurred in December 2009 as a result of a >10-fold increase of *Fritillaria* sp. (a genus of solitary, free-swimming, tunicate or “sea-squirts”). Like most tunicates, species in this genus are filter feeders, and its high abundance in December 2009 corresponded to unusually high Chl-a throughout the RS region. There has been a statistically significant trend of increasing zooplankton abundance in all zones of the East Antarctic region since 1991, but no increasing trend in zooplankton abundance in the RS region was discernible over the sampling period 2006–2013. There was no significant trend in the average size of the copepods in the Ross Sea region during the sampling period, but the East Antarctic showed a trend towards larger copepod species from 1991.

Keywords: CPR zooplankton data, Southern Ocean

Poster presentation

Potential habitat patterns of neon flying squid in central North Pacific in response to high-frequency climate oscillations

Saitoh S.I. and Alabia I.

Marine ecosystems are sensitive to impacts of environmental variability ensuing from high-frequency climate oscillations that elicit biological responses manifested through changes in species abundance and distribution. In this study, we explored the influence of environmental and high-frequency, short periodic climate variability on potential habitat distribution of neon flying squid (*Ommastrephes bartramii*) in central North Pacific from May-July 1999-2011. We also examined the potential habitat patterns in relation to dominant spatial and temporal modes of variability in environmental data derived from empirical orthogonal function (EOF) analysis. Squid potential habitats were deduced using a generalized additive model generated from monthly fishery data, environmental parameters (sea surface temperature, sea surface salinity, sea surface height and eddy kinetic energy) and climate proxy (southern oscillation index). Inferred potential habitat revealed habitat suitability index (HSI) differences in extent and magnitude, presumably from changes linked to intra-decadal climate oscillation. Primary EOF mode (21.0%) for SSH revealed temporal patterns reflecting both the seasonal and inter-annual signals and captured elevated SSH from 2009-2011. Interestingly, primary EOF mode (13.0%) for EKE showed alternating periods of high (2002-2004; 2010-2011) and low (1999-2001; 2005-2009) EKE. These signals could exert considerable environmental changes that in turn, impact squid habitat in the region. These results could contribute to the understanding of marine ecosystem response to high-frequency and short-term climate perturbations, important for resource management and adaptive strategies.

Keywords: potential habitat, flying squid, North Pacific

Poster presentation

Empirical evidence for different cognitive effects in explaining the attribution of marine range shifts to climate change

van Putten I.E., Frusher S., Fulton E.A. and Hobday A.J.

The changing geographical distribution of species, or range shift, is one of the better documented fingerprints of climate change in the marine environment. Range shifts often involve dramatic changes in the distribution of economic, social and cultural opportunities and challenge marine resource users' capacity to adapt to a changing climate and managers' ability to implement adaptation plans. In particular, a reluctance to attribute marine range shift to climate change can undermine the effectiveness of climate change communications and pose a barrier to successful adaptation. Attribution is a known powerful predictor of behavioural intention, making understanding the cognitive processes that underpin the formation of marine resource users' beliefs about the cause of observed marine range shift phenomena an important topic for research. An examination of the attribution by marine resource users of three types of range shifts experienced in a marine climate change hotspot in south east Australia to various climate and non-climate drivers, indicates the existence of at least three contributing cognitions. That is, i) engrained mental representations for environmental phenomena, ii) scientific complexity in the attribution pathway, and iii) dissonance from the positive or negative nature of the impact are all found to play a part in explaining the complex pattern of attribution of marine climate change range shift.

Keywords: Climate change, range shift, coastal communities

Oral presentation

Workshop 6: Paradigm shift in plankton ecology: the central role of mixotrophic protists in future oceans

Conveners

- **Aditee Mitra**
Centre for Sustainable Aquatic Research, Swansea University
Swansea, UK
A.Mitra@swansea.ac.uk
- **Diane Stoecker**
Horn Point Laboratory, University of Maryland
Cambridge, USA
stoecker@umces.edu
- **Hae Jin Jeong**
Ecology & Bioenergy Laboratory, Seoul National University
Seoul, Korea
hjjeong@snu.ac.kr
- **Elizabeth Fulton**
Marine and Atmospheric Research, Commonwealth Scientific and Industrial Research Organisation
Hobart, Australia
beth.fulton@csiro.au

Description of the workshop

Planktonic primary production is a cornerstone process in planetary biogeochemical cycling with associated interactions with climate change. Traditional descriptions of the planktonic food-web link inorganic nutrients to autotrophic phytoplankton, to the heterotrophic zooplankton and then eventually to fisheries production, with the microbial loop channelling nutrient regeneration through bacteria and microzooplankton. Recent work, stemming from a Leverhulme funded International Network, challenges this traditional paradigm, arguing that open water marine ecology is heavily dependent upon the activity of protists that are mixotrophic (i.e., single-celled organisms capable of photosynthesis as well as phagotrophy). Mixotrophy is not confined to a single protist group rather it is employed by a variety of “phytoplankton” and “microzooplankton” groups, occurring widely in oceanic and coastal as well as fresh water systems. Mixotrophic “phytoplankton” dominate primary production most of the time; for example, thriving in summer temperate waters (which support the bulk of fisheries production), and in oligotrophic systems (which cover the bulk of the oceans). The combination of predatory activity, anti-grazing and varied nutritional capabilities, potentially renders mixotrophs supreme bloom forming organisms. At the extreme, mixotrophs can form harmful algal blooms responsible for severe socio-ecological damage such as fish kills.

Increases in eutrophication, driven by anthropogenic inputs especially due to growing human populations, and increases in the stability of the water column, predicted under

Workshop 6: Paradigm shift in plankton ecology

climate change, may equally favour mixotrophic dominance due to their ability to flourish in high nutrient eutrophic systems as well as low nutrient, ecologically mature systems. Therefore, by shifting the flow of materials and forming blooms, mixotrophs can affect the structure and function of other parts of the food web and human societies. In terms of socioeconomic impacts they can cause direct losses through impacting water quality and contaminating shellfish cultures and fisheries, indirectly they can shift energy pathways and thence affect the relative composition and flows of ecosystems specifically in relation to fisheries which would have immense societal effects. All these processes and events represent a major shift in the way that we see the functioning of food-webs and biogeochemical cycling in marine ecosystems from the coastal zones to mid-oceans. This has important implications for both the natural environment and human society. This workshop will bring together researchers from across disciplines to explore the implications for this paradigm shift in our perception of planktonic ecosystems upon marine science and society. The vision behind this workshop is to spread the science to a much wider audience, to embed the concept of the importance of mixotrophic protists in open water ecology, into mainstream marine ecology and biogeochemistry, and to socio-economics (specifically in view of the role of mixotrophs in HABs and in trophic upgrading to support fisheries).

Workshop Programme

Oral Presentations

Monday 23 June 2014, 09:00-10:30

Chair: Diane Stoecker

Room D4

Time	Presenter	Title
09:00-09:30	Mitra, Aditee	Workshop background & Aim for the day
09:30-09:50	Jakobsen, Hans	The role of pH feedback on phytoplankton community development in nutrient amended mesocosmos
09:50-10:10	Berger, Stella	How does increased CO ₂ and iron availability affect mixotrophs, ciliates and mesozooplankton in a coastal marine system?
10:10-10:30	All	Discussion

Monday 23 June 2014, 11:00-12.30

Chair: Hae Jin Jeong

Room D4

Time	Presenter	Title
11.00-11:20	Bouvet, Antoine	Phytoplankton communities in the Western Arctic Ocean during the sea ice melt record of 2012
11:20-11:40	Lee, Sung Yeon	Mixotrophy in the phototrophic dinoflagellate <i>Symbiodinium voratum</i>
11:40-11:50	Martin-Jézéquel, Véronique	Mixotrophy of harmful diatoms? The case of organic nutrition in the genus <i>Pseudo-nitzschia</i>
11:50-12:30	All	Discussion

Workshop 6: Paradigm shift in plankton ecology

Monday 23 June 2014, 14.30-16.00

Chair: Beth Fulton

Room D4

Time	Presenter	Title
14:30-14:50	Ghyoot, Caroline	Modelling <i>Phaeocystis globosa</i> mixotrophy under phosphate limitation
14:50-15:10	Våge, Selina	Successful strategies in size-structured mixotrophic food webs
15.10-16.00	All	Discussion

Monday 23 June 2014, 16.30-18.00

Chair: Aditee Mitra

Room D4

Time	Presenter	Title
16.30-18.00	All	Discussion – how to facilitate a better appreciation of planktonic mixotrophy

Poster Presentation

Monday 23 June 2014, 13:30-14:30, Poster Session for Workshops

ID	Presenter	Title
W6.P1	Martin-Jézéquel, Véronique	Mixotrophy of harmful diatoms? The case of organic nutrition in the genus <i>Pseudo-nitzschia</i>

How does increased CO₂ and iron availability affect mixotrophs, ciliates and mesozooplankton in a coastal marine system?

Berger S.A., Simonelli P., Ray J., Tsagaraki T., Fernández J.A., Lorenzo M.R., Maldonado M., Egge J., Larsen A., Jakobsen H.H. and Segovia, M.

To explore the effects of environmental changes of CO₂ levels and iron availability on marine plankton communities we performed a mesocosm experiment in the Raunefjord off Bergen, Norway. Mesocosms were filled with fjord water at the time of an early summer diatom bloom in June 2012. We used a two x two full factorial design to test the effects of increased CO₂ and changes in dissolved iron concentrations. The carbonate system in the mesocosms (11 m³) was manipulated before the start of the experiment to generate two CO₂ levels: ambient (LC, 390 ppmV) and increased CO₂ (year 2100 prediction, HC, 900 ppmV). The siderophore desferoxamine B (DFB) was added to half of the mesocosms on day 7 at a concentration of 70 nM. This DFB addition (+DFB), as well as the high CO₂, resulted in a 3-fold increase in dissolved iron (dFe) by day 17 (from ~4 nM to 12 nM). At the beginning of the experiment nitrate and phosphate (30:1 molar ratio) were added to all mesocosms to promote a phytoplankton bloom. We followed the microplankton dynamics for 22 days and sampled mesozooplankton at the beginning and at the end of the experiment. Two phases of phytoplankton development could be distinguished. The first phase was dominated by a decay of the initial diatom bloom (mainly *Skeletonema* sp.), evidenced by a similar decline in chlorophyll-a concentration in all treatments until day 10. In this phase, ciliates peaked around day 6, likely following the pico- and nanoplankton, and showed highest abundances at HC -DFB, but not at HC +DFB. The first dinoflagellate peak of the genus *Ceratium* sp. was around day 8 regardless of the treatments. In the second phase (days 10-22), ciliates remained at very low levels, but the mixotrophic *Ceratium* sp. increased in LC -DFB treatments, indicating that mixotrophy may compensate for lower dFe levels. Further results on the responses of other mixotrophs, including *Dinobryon*, *Phaeocystis*, and dinoflagellates, will be presented. While the total mesozooplankton abundance at the end of the experiment showed no clear treatment effects, we did, however, observe treatment effects in variety of mesozooplankton taxa. Most prominent was the negative effect of HC on the cyclopoid copepod *Oithona* sp. independent of DFB, while appendicularian zooplankton showed the opposite response. Appendicularian abundance was highest in HC -DFB, medium in HC +DFB, but decreased in LC +DFB treatments suggesting that increased dissolved iron levels had a deleterious effect on them.

Keywords: carbon-dioxide, iron availability, mixotrophy, mesozooplankton, mesocosm

Oral presentation

Phytoplankton communities in the Western Arctic Ocean during the sea ice melt record of 2012

Bouvet A., Ruiz-Pino D., Chen J., Hao Q. and Jin H.

A drastic sea ice melting has been occurring in the Arctic Ocean during the last decade. Related to global climate change this melt could produce a drastic change in the phytoplanktonic communities which have a key role in the ecosystem's richness and the biological carbon pump. In summer 2012 the phytoplankton distribution related to nutrient and hydrological conditions were documented during the CHINARE 2012 transpolar oceanographic cruise conducted onboard the icebreaker Xuelong. In situ taxonomic observations of the main phytoplankton functional groups and Chlorophyll biomass obtained across the Western Arctic (67-86°N) allows to characterize the regional distribution of primary producers during the record of sea ice melt. The majority of the surface water was indeed ice free between 60°N and 82°N. This fully open water and the presence of sea ice cover still thick (75%) at 71°N and also north of 83°N were characterized by different phytoplankton populations and biomass.

The central Chukchi Sea (67-71°N) exhibited distribution of phytoplankton characterized by a peak bloom in July and a late bloom in September. The highest chlorophyll and phytoplankton abundances were observed around two still heavily icy areas: i) Paroxysm bloom conditions prevailed at 71°N, where despite a high sea ice cover (75%) the chlorophyll was the highest and the phytoplankton community was dominated by centric diatoms (*Chaetoceros* spp., *Thalassiosira* spp.), by cryopelagic pennate species (*Fragilariopsis* spp., *Navicula* spp.) and the Prymnesiophyceae *Phaeocystis* sp.. ii) Bloom conditions were also found at heavily ice covered observed in high latitudes (83-86°N). Surface phytoplankton biomass and Chla were 8 and 2 times higher than in ice free basin. Diatoms were abundant and mostly represented by sea ice related species. Weak sea water stratification led a shallower DCM (20m) where carbon biomass was 3 times lower than in surface and phytoplankton communities were dominated by small flagellates and small Gymniodiales dinoflagellates. The intensity and diversity of the bloom formed around these two ice cover, suggest that phytoplankton cells in high abundance and productivity can grow well under thick ice. Compared to the waters which have been ice free since 15 to 60 days, it appears that these oasis of sea ice concentrated the highest summer phytoplankton biomass and biodiversity. Conversely, the Makarov Basin appears as a very oligotrophic area, characterized by very low phytoplankton carbon biomass, Chla concentration and a very deep DCM (48m). This extreme oligotrophy is related to a high abundance of small flagellates representing 95% of the total cells.

The 2012 summer ice record melt was produced simultaneously oases of fertility around high sea ice cover and extended Marginal Ice Zones where diatoms was abundant and an extreme oligotrophy in ice free basin and a dominance of flagellates. The taxonomic distribution of phytoplankton as detected during this record of sea ice melt provides a major constraint to improve forecasts and to analyze the response of the food chain and fisheries in the Arctic to all parameter affected by the recent climate changes.

Keywords: Arctic, Ice melting, Phytoplankton, Biodiversity, Biomass

Oral presentation

Modelling *Phaeocystis globosa* mixotrophy under phosphate limitation

Ghyoot C., Lancelot C. and Gypens N.

We present a conceptual model describing the mixotrophic ability of *Phaeocystis globosa* to use dissolved organic phosphorus (DOP) when dissolved inorganic phosphate (DIP) is limiting. This phytoplankton has been shown to synthesize alkaline phosphatases (AP) releasing DIP from DOP. Two mechanisms of AP induction are explored: (i) driven by an external DIP threshold and (ii) driven by an internal energy trade-off. The two mechanisms are tested and compared in a P-depleted mesocosm and sensitivity analyses are performed both on P metabolism parameters and on DIP vs DOP relative availability. Both mechanisms largely increase the simulated maximum biomass reached when compared to strict phototrophy and the importance of additional biomass is mainly controlled by the combination of the P availability and parameters regulating the DOP hydrolysis. Further simulations testing the competition between *P. globosa* and a phototrophic diatom suggest that mixotrophy have a significant impact on the outcome of the two species. Finally, the effect of mixotrophy on food web interactions and the biogeochemical cycles is studied by integration of the simple module of mixotrophy in the existing MIRO model describing the planktonic ecosystem of the DIP-limited Southern North Sea where *P. globosa* blooms occur every spring. The complex model run over the period 1985-2005 suggests that mixotrophy on DOP maintains the *P. globosa* spring blooms over years in the Belgian coast despite the reduction of the DIP loads since the late 80s.

Keywords: modelling, mixotrophy, Phaeocystis

Oral presentation

The role of pH feedback on phytoplankton community development in nutrient amended mesocosmos

Jakobsen H., Blanda E., Jepsen M. P., Rayner T., Højgaard J., Staehr A.P., Novac A. and Hansen W.B.

In a series of mesocosms exposed to different nutrient doses were the interactions between pH, respiration, phytoplankton and photosynthesis studied. We found the administration of nutrient doses governed the phytoplankton community. For an example increased the invasive nuisance algae *Alexandrium pseudogonyaulax* in nutrient amended mesocosms showing a nutrient dose dependent response. The occurrence of *A. pseudogonyaulax* apparently controlled Chla at a steady level. However, the pH increased and reached a critical limit that arrested growth and caused a decline of *A. pseudogonyaulax* which then became replaced by pH tolerant *Prorocentrum* species. Two out of the three recorded *Prorocentrum* species are invasive to local waters. This increase in *Prorocentrum* biomass was parallel to an increase in Chla and concurred with the disappearance of *Alexandrium pseudogonyaulax* from the water column. *A. pseudogonyaulax* is a mixotrophic dinoflagellate that kills ambient phytoplankters non-selectively and engulfs them. That is; ambient phytoplankters were killed but not necessarily engulfed. This feeding seemed to be more critical to diatoms that completely disappeared in the treatment with the highest peak concentration of *A. pseudogonyaulax*. Thus, diatoms were flourishing in the *A. pseudogonyaulax* free control. Once *A. pseudogonyaulax* disappeared from the water column, diatoms recovered in the treatment that had have the lowest maximal *Alexandrium pseudogonyaulax* abundance whereas no diatoms were observed in the treatment that displayed the highest maximal abundance of *A. pseudogonyaulax*. Community gross primary production (GPP), respiration (R) and net ecosystem production (NEP = GPP-R) were measured using the diel oxygen technique and converted into community carbon metabolic rates. We found significant higher GPP and NEP in the nutrient amended mesocosms whereas the control was much lower. Moreover, there was large drop in both GPP and NEP concurring with the peak phytoplankton abundance but we found no overall effect similar to the nutrient dose specific developments found among phytoplankton. The dinoflagellates *A. pseudogonyaulax* and some of the blooming *Prorocentrum* spp. were not recorded in the area until about 20 yrs ago and their occurrence may be a product of increased ocean temperatures and eutrophication.

Keywords: dinoflagellates, mixotrophy, nuisance algae , pH

Oral presentation

Mixotrophy in the phototrophic dinoflagellate *Symbiodinium voratum*

Lee S.Y., Jeong H.J., Yoo Y.D., Kang N.S., Lim A.S., Lee M.J. and Lee K.H.

Survival of free-living and symbiotic dinoflagellates (*Symbiodinium* spp.) in coral reefs is critical to the maintenance of a healthy coral community. Most coral reefs exist in oligotrophic waters, and their survival strategy in such nutrient-depleted waters remains largely unknown. In this study, we found that two strains of *Symbiodinium* spp. cultured from the environment and acquired from the tissues of the coral *Alveopora japonica* had the ability to feed heterotrophically. *Symbiodinium* spp. fed on heterotrophic bacteria, cyanobacteria (*Synechococcus* spp.), and small microalgae in both nutrient-replete and nutrient-depleted conditions. Cultured free-living *Symbiodinium* spp. displayed no autotrophic growth under nitrogen-depleted conditions, but grew when provided with prey. Our results indicate that *Symbiodinium* spp.'s mixotrophic activity greatly increases their chance of survival and their population growth under nitrogen-depleted conditions, which tend to prevail in coral habitats. In particular, free-living *Symbiodinium* cells acquired considerable nitrogen from algal prey, comparable to or greater than the direct uptake of ammonium, nitrate, nitrite, or urea. In addition, free-living *Symbiodinium* spp. can be a sink for planktonic cyanobacteria (*Synechococcus* spp.) and remove substantial portions of *Synechococcus* populations from coral reef waters. Our discovery of *Symbiodinium*'s feeding alters our conventional views of the survival strategies of photosynthetic *Symbiodinium* and corals.

Keywords: mixotrophy, zooxanthella, coral bleaching, food web

Oral presentation

Mixotrophy of harmful diatoms? The case of organic nutrition in the genus *Pseudo-nitzschia*

Martin Jézéquel V. and Calu G.

The importance and wide distribution of the toxigenic diatom *Pseudo-nitzschia* open the question on its cosmopolitan nature and adaptation in marine systems. The presence of its toxin, domoïc acid (DA), has negative consequences on marine wildlife at various levels within the food webs, strenghtening the interest to understand its production. Large blooms of *Pseudo-nitzschia* mostly occurred in coastal areas. Thanks to the eutrophication in these waters, the diatom may undergo variable nutritional conditions. In particular, major inputs of organic components would drive its growth and DA production. Here we summarize knowledge and show laboratory data on *Pseudo-nitzschia* growing under organic sources. We look into physiological explanations for the consequences of this nutrition on the occurrence and nuisance of this toxic genus.

Keywords: diatom, organic nutrition, domoïc acid

Oral and Poster presentations

Successful strategies in size-structured mixotrophic food webs

Våge S., Castellani M., Giske J. and Thingstad T.F.

Unicellular mixotrophic organisms that combine osmotrophy and primary production with phagotrophy account for significant amounts of primary production and bacterivory in marine environments, yet mixotrophs are still usually absent in large scale biogeochemical models. We present a thorough analysis of a food web model with fine resolution in both cell size and foraging mode, where foraging mode is a strategy ranging from pure osmotrophy to pure phagotrophy. The study investigates emerging food web structures based on different mixotrophic life strategies. A trade-off for maximum uptake rates of mixotrophs is incorporated. We study how different factors determine the emergent food web structure, here represented by the topology of the distribution of given amounts of total phosphorous over the cell size-foraging mode plane. Consistent with the observed prevalence of mixotrophs in recent oceanographic surveys, we find that mixotrophs successfully coexist with foraging specialists (pure osmo- or phagotrophs) for a wide range of conditions, occasionally even outcompeting the specialists. Mixotrophy trade-off and size dependent parameters have a strong effect on the emerging community structure, stressing the importance of foraging mode and size considerations when working with microbial diversity and food web dynamics.

Keywords: High-resolution planktonic food-web model, mixotrophy, coexistence

Oral presentation

Workshop 7: Approaches to predicting fish from physics: strengths, weaknesses and ways forward

Conveners

- **Eric Galbraith**
Dept. of Earth & Planetary Sciences, McGill University
Montreal, Canada
eric.galbraith@mcgill.ca
- **James Watson**
Dept. of Atmospheric and Oceanic Sciences, Princeton University
Princeton, USA
jrwatson@princeton.edu
- **Myron Peck**
Institute of Hydrobiology and Fisheries Science, University of Hamburg
Hamburg, Germany
myron.peck@uni-hamburg.de

Description of the workshop

Tremendous progress has been made in simulating fish biomass from the physics of marine environments. Three-dimensional ocean circulation models predict the distribution of light, temperature and nutrients, driving primary production, which is then transferred to upper trophic levels to provide a spatially- and temporally-resolved prediction of fish biomass. The focus of this workshop will be on the latter part of the problem: the transfer of primary production to upper trophic levels.

At present, the transfer of biomass to upper trophic levels is being tackled through a number of approaches of varying complexity, from simple size-spectrum models to complex species-resolved ecosystem models. Most of these have been developed only in the last few years, by groups working in parallel, with little inter-comparison. The success of all approaches is limited to the strength with which available data can be used to constrain them. We invite contributions on the topic of predicting the abundance and distribution of fish, with the explicit understanding that the goal of this session is to compare related works, both with each other and with data, and to identify key weaknesses and strengths of the various tools employed. A significant part of this session will be devoted to discussing ways in which to move forward in light of the work presented. Data assessments, numerical simulations and mathematical theory are all welcome.

Workshop 7: Approaches to predicting fish from physics

Workshop Programme

Oral presentations

Monday 23 June 2014, 09:00-09:30

Room K1

Time	Presenter	Title
09:00-09:25		W3+W7+W8 Joint introduction (overview of the three workshops, and a few words from the organizers of the Fish Model Intercomparison Project, FishMIP)

Monday 23 June 2014, 09:30-10:30

Room K3

Time	Presenter	Title
09:30-10:30		Speed talks (max. 2.5 min. each). No questions
	Christensen, Villy	The global ocean is an ecosystem: Simulating marine life and fisheries
	Galbraith, Eric	The Bioeconomic Open Access Trophic Size-spectrum model (BOATS): An Earth-System approach to fisheries and fisheries economics
	Eddy, Tyler	Approaches to predicting fish from physics: strengths, weaknesses and ways forward
	Kearney, Kelly	How does uncertainty in model structure and parameterization affect the propagation of primary production through a marine food web?
	Lehodey, Patrick	Coupling 3-D models of ocean physics and biogeochemistry to fish population dynamics to monitor marine living resources under the influence of fishing and climate
	Payne, Mark	In search of low-hanging fruit: are there any shortcuts to near-term prediction in North Atlantic marine ecosystems?
	Roy, Tilla	A global assessment of size-structured pelagic biomass in an end-to-end biogeochemical ocean circulation model.
	Steenbeek, Jeroen	Advances in spatial-temporal food web modelling with Ecospace
	Tittensor, Derek	Inter-comparison of global fisheries and ecosystem models
	Lindstrøm, Ulf	Non-deterministic modelling of biomass transfer in food-webs
	Lotze, Heike	Modeling the impacts of climate change on fisheries and marine ecosystems (FISH-MIP): A new model intercomparison project

Workshop 7: Approaches to predicting fish from physics

Monday 23 June 2014, 11:00-12:30

Room K3

Time	Presenter	Title
11:00-11:30	Tittensor, Derek	What is the best way to evaluate model results and judge model skill?
11:30-12:00	Lehodey, Patrick	Is movement important? If so, how do we model it?
12:00-12:30	Planque, Benjamin	Is Type II feeding enough? How do we choose the right level of food-web complexity?

Monday 23 June 2014, 14:30-16:00

Room K3

Time	Presenter	Title
14:30-15:15	Christensen, Villy	How can we generate future fish harvest scenarios?
15:15-16:00	Kearney, Kelly	What are the most critical uncertainties we need to address in the models, how does error propagate?

Monday 23 June 2014, 16:30-18:00

Room K3

Time	Presenter	Title
16:00-17:00	All	Preparation of the W7 synthesis. Discussion on the preparation of a potential synthesis paper

Monday 23 June 2014, 17:30-18:30

Room K1

Time	Presenter	Title
17:00-18:00		W3+W7+W8 plenary synthesis (each workshop gives a ~20 minute summary, 30 minutes for open discussion)

The global ocean is an ecosystem: Simulating marine life and fisheries

Christensen V., Coll, M. Buszowski, J., Cheung W.W.L., Frölicher T., Steenbeek J., Stock C.A., Watson R.A., Walters and C.J.

There is considerable effort allocated to understanding how climate change impacts our physical environment, but comparatively little to how life on Earth will be impacted. Therefore, we have developed a modeling complex for evaluating the combined impact of fisheries and climate change on upper-trophic level organisms in the global ocean, including invertebrates, fish and other large vertebrates. The modeling complex has a food web model as core, spanning from primary producers through to top predators and fisheries. It obtains environmental productivity from a biogeochemical model, and assigns global fishing effort spatially. We tuned model parameters based on Markov Chain random walk stock reduction analysis, fitting the model to historic catches. We evaluated the goodness-of-fit of the model to data for major functional groups, by spatial management units, and globally. The modeling complex is developed to initially evaluate how abundance of higher trophic levels in the global ocean has changed from 1950 to the present. We found that the model could replicate broad patterns of food web production with best agreement for the total catches, good agreement for species' groups, and with more variation at the regional level. It is likely that improvements to the global fleet database will improve the spatial effort distribution. We also found that the global fish biomass since 1950 has declined with almost half for the medium-sized and larger fish, and has changed little for the smaller fish.

Keywords: Global, biomass, end-to-end, tuning, model coupling

Oral presentation

The bioeconomic open access trophic size-spectrum model (BOATS): An Earth-System approach to fisheries and fisheries economics

Carozza D.A., [Galbraith E.D.](#) and Bianchi D.

Fisheries and fisheries economics have generally been focussed on particular regions, species, and markets. We instead model fisheries as part of a globally coupled system that is based on fundamental physical, ecological, and economic principles. The Bioeconomic Open-Access Trophic Size-structure (BOATS) model provides an Earth-system perspective to fisheries that illuminates global patterns of biomass, harvest, and revenue that are not possible with more specialized studies. As a result of our global approach and due to the rich complexity of the ecosystems that fisheries are a part of, we parameterize certain features of the ecosystem dynamics in order to concentrate on the first-order drivers of biomass and on the interactions with climate and harvesting. In particular, instead of explicitly modeling predation, we employ an empirical parameterization of mortality. Moreover, we use a model based on primary production and temperature to determine the average phytoplankton cell size, and parameterize the resource spectrum. To calculate growth, reproduction, and mortality in different fish groups categorized by their asymptotic size, we use primary production and temperature data and apply concepts from the metabolic theory of ecology and size-based ecological theory. Harvesting has a long history of impacting fisheries. To capture the inherently economic nature of harvesting, we apply the classic Gordon-Schaefer fisheries economic model, and so assume that the core economic character of fisheries is represented by the open access framework, whereby the time evolution of harvesting effort is proportional revenue per unit effort. This Earth-system approach to fisheries is ideally suited to study the interactions between fisheries and climate, while integrating core economic features such as technology, ex-vessel price, and the cost of effort, on the global scale.

Keywords: Earth-system model, fisheries, allometric, open-access harvesting

Oral presentation

Approaches to predicting fish from physics: strengths, weaknesses and ways forward

Eddy T.D., Tittensor D., Huber V., Heike K. and Lotze H.K.

The Fisheries and Marine Ecosystems Model Intercomparison Project (FISH-MIP) is part of the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP), hosted by the Potsdam Institute for Climate Impact Research (PIK), Germany. FISH-MIP aims to develop a common simulation protocol using up-to-date climate projections (based on representative concentration pathways; RCP) and consistent socio-economic input data (shared socioeconomic pathways; SSPs) to be used among fisheries and ecosystem models. To date, most of the research on fisheries and ecosystem models has been taking place on regional scales, however there are several recent efforts to produce global models. FISH-MIP aims to compare output among regional models, as well as among regional and global models. In this presentation, I will describe three commonly employed regional ecosystem modeling platforms: Atlantis, Ecopath with Ecosim (EwE), and OSMOSE, and discuss how they compare in terms of model structure, data requirements, and model outputs. I will highlight focus regions where models have been developed for all three platforms that will allow for comparisons amongst them. The goal of FISH-MIP is to be able to compare the output from these regional models to corresponding areas from global output. I will also address some of the challenges of comparing output from regional models and global models, and possible ways forward. The overall ISI-MIP project also aims to link sectors, and I will discuss potential ways that regional ecosystem models could be informed by the agriculture and groundwater sectors.

Keywords: regional ecosystem modelling intercomparison, climate impacts

Oral presentation

How does uncertainty in model structure and parameterization affect the propagation of primary production through a marine food web?

Kearney K., Stock C. and Sarmiento J.L.

Complex end-to-end ecosystem models incorporate many sources of uncertainty, including the choice of processes included in the models, the functional forms chosen for those processes, and the values given to the parameters that define each process. Here, we will present an end-to-end ecosystem model that couples physics, biogeochemistry, and upper trophic level predator-prey dynamics for the Eastern Subarctic Pacific ecosystem. This model provides a method for incorporating the often-large observational uncertainty related to food web processes into predictions through an ensemble parameterization technique. We also quantify how two types of uncertainty (observational and measurement uncertainty, which constrains the parameters used in the model, and structural uncertainty regarding the functional form of non-predatory mortality) can affect the propagation of primary productivity to higher trophic levels.

Keywords: end-to-end ecosystem model, subarctic Pacific

Oral presentation

Coupling 3-D models of ocean physics and biogeochemistry to fish population dynamics to monitor marine living resources under the influence of fishing and climate

Lehodey P., Senina I. and Gaspar P.

A modelling approach is developed to predict and analyze the spatial dynamics of marine exploited and protected species with mechanisms constrained by relationships based on the bio-physical environment predicted from coupled 3D models of ocean physics and biogeochemistry. This spatial Eulerian ecosystem and population dynamics model (SEAPODYM) is based on advection-diffusion equations simulating random and oriented movements. First the model includes a simplified representation of micronekton at the mid-trophic level of the oceanic food web with several functional groups. Then spatio-temporal dynamics of predators, exploited or protected species, are simulated under the influence of environment and fishing pressure. Surface currents passively transport larvae, while young and adult fish movements are driven using habitat indices. Advection and diffusion are proportional to the size of the fish and the advection term is proportional to the gradient of habitat, while the diffusion decreases when the habitat index increases. For mature fish, the habitat index switches seasonally from the feeding to the spawning habitat definition in order to reproduce changes in migration patterns of mature fish during the spawning season. The spawning habitat index in SEAPODYM also drives the spawning success, and then the subsequent recruitment. Fisheries impacts are included in the model and the comparison between predicted and observed catch used to optimize the model parameterization using the maximum likelihood method. This model has been used to obtain optimised parameterization and quantitative stock estimates for several tuna species over past and present fishing periods. Projection under Climate Change scenarios were also explored for three tuna species in the Pacific Ocean.

Keywords: Ecosystem, Modeling, Population Dynamics, Fisheries, Climate

Oral presentation

Non-deterministic modelling of biomass transfer in food-webs

Lindstøm U., Planque B. and Subbey S.

Modelling marine ecosystems is extremely difficult not the least due to the number and complexity of ecological processes i.e. "the curse of dimensionality" (Yodzis and Innes, 1992), the non-linearities, and the spatial and temporal scales that need to be taken into account. It is impossible and probably not required to include all details of the ecosystem to understand and predict how some parts of ecosystems behave. The challenge is to decide which processes at lower levels of organisation need to be considered to predict emergent properties of higher levels of organisation. For example, the transfer of energy between trophic levels emerges from individuals, their behaviour and energetic demands; do we need to know these details to model the energy transfer between trophic levels? By using a non-deterministic food web model, constrained by mass-balance, inertia and satiation, we simulate the foodweb dynamics, and thus the biomass transfer between trophospecies. We apply this model to the Barents Sea ecosystem and examine the emergent properties of the Barents Sea food web, such as temporal autocorrelation in biomass time series, functional responses (biomass transfer), integrated diet fractions etc. Interestingly, despite fluxes of biomass between trophospecies being random - i.e. the consumption rates as a function of prey biomass are random - non-linear functional response relationships of some trophospecies emerge.

Keywords: foodweb, model, Barents Sea, stochastic

Oral presentation

Modeling the impacts of climate change on fisheries and marine ecosystems (FISH-MIP): A new model intercomparison project

Lotze H.K., Eddy T., Tittensor D. and Huber V.

Predicting the impacts of climate change on natural and human systems has become of increasing importance to inform science, decision makers and the general public. There are many different approaches to model climate impacts on specific systems; however, it is often unclear how well the predicted model outcomes compare due to underlying differences in model structure. Results are also often not directly comparable across systems due to the missing harmonization of input data. The Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP), hosted by the Potsdam Institute for Climate Impact Research (PIK) in Germany, aims to address this issue by comparing model predictions within and across different sectors, such as agriculture, forestry, hydrology, and health. The goal is that all modelers use a common simulation protocol including a range of future greenhouse gas scenarios (representative concentration pathways; RCPs) and shared socioeconomic pathways (SSPs). Recently, a new sector has been launched for the marine environment: the Fisheries and Marine Ecosystems Model Intercomparison Project (FISH-MIP). So far, FISH-MIP includes several regional ecosystem models and a growing number of global ecosystem models. In this presentation, we will provide an introduction to and overview on FISH-MIP, including its goals, participating models, modeling scenarios, and the state of the common simulation protocol. We will also address challenges and opportunities to set the stage for input from and discussions among marine ecosystem modelers. Lastly, we will introduce potential inter-sector comparisons within the overall ISI-MIP framework.

Keywords: climate-impacts, ecosystem-models, global-fisheries, future-predictions, model-intercomparison

Oral presentation

In search of low-hanging fruit: are there any shortcuts to near-term prediction in North Atlantic marine ecosystems?

Payne M.R. and Hatun H.

We present the results of a recent review assessing the potential for inter-annual to decadal predictions in marine ecosystem. Predictions in marine ecosystems are usually viewed with a high degree of scepticism, and rightly so: this notoriously challenging task has frustrated generations of marine scientists and as a result research in this field has almost become dormant. However, we propose that the time may be right for a re-examination of predictive aspects of marine science. Recent advances in earth system and oceanographic circulation models have yielded evidence of multi-annual and even sub-decadal predictive skill in the Northeastern Atlantic Ocean for some variables. The challenge for biological science is then to translate this potential physical predictability into biological predictability. One approach is via fully coupled ecosystem models: however, simpler approaches may also be feasible. We review here how this could be done by first examining the failures of the past and focusing on the question of what a predictable biological quantity would look like. We then present the results of an extensive literature review that attempts to identify biological outcomes that are potentially predictable. We therefore address the question, are there any low-hanging fruit in the inter-annual to decadal predictions of marine ecosystems?

Keywords: fish; predictions; forecasts; physics; decadal-scale

Oral presentation

A global assessment of size-structured pelagic biomass in an end-to-end biogeochemical ocean circulation model

Roy T., Fulton E.A. and Fogarty M.

Recently a dynamical marine ecosystem model, NEMO-PISCES-APECOSM (NPA), has been developed that can simulate both the impacts of fishing pressure and climate change on the pelagic marine ecosystem at the global scale. Here, the global 3D distribution of size-structured biomass is simulated using a biogeochemical ocean circulation model (NEMO-PISCES) coupled to an end-to-end marine ecosystem model (APECOSM), whereby the transfer of energy up the marine food-chain is calculated based on the Dynamical Energy Budget (DEB) theory. Biomass spectra, the distribution of biomass over different marine organism size classes, have been shown to be useful indicators of the change in the structure of marine ecosystems. The NPA model can be used to explore how climate change and fishing perturb the distribution of biomass spectra. Yet, the evaluation of the simulated size-structured biomass has proved challenging because, up until now, few observational products have been available.

Here we use estimates of the total regional fishery potential from a recent FAO report to evaluate the biomasses simulated in the NPA model. The total fishery potential across trophic levels is derived from satellite-based estimates of primary production and ecological transfer efficiencies from a large number of regional energy flow network models (ECOPATH with ECOSIM). We evaluate the NPA model performance over the coastal Large-Marine Ecosystem (LME) and open ocean Food and Agricultural Organization of the United Nations (FAO) regions for which satellite-derived estimates and transfer efficiencies could be derived, and over 5 ecotypes: "subarctic and boreal", "temperate", "subtropical", "tropical" and "upwelling". We discuss the potential implications of model performance on long-term projections of marine ecosystem dynamics.

Keywords: fisheries, pelagic biomass, biogeochemical circulation model,

Oral presentation

Advances in spatial-temporal food web modelling with Ecospace

Steenbeek J., Coll M., Buszowski J., Christensen V. and Walters C.

Species distribution models use a combination of physical, environmental, ecological and physiological data to predict species distribution but have limited ability to take trophic interactions within food webs into account. These interactions have been shown to be key elements for understanding species and ecosystems dynamics in the ocean.

The Ecopath with Ecosim approach and software (EwE) is one of the most widely applied ecological modelling tools. EwE describes ecosystem food-web models by means of functional groups, each representing a species, a sub-group of a species or a group of species that have functional and ecological similarities. EwE integrates a large body of information from the ecosystem in a coherent description of aquatic food webs and places human activities in an ecosystem context. At present, EwE models are widely used to study the structure and functioning of marine ecosystems, perform ecosystem comparisons, derive emergent properties, assess the impacts of human activities including climate change and fishing impacts, analyse management options for marine resources, and describe bioaccumulation of toxins in the food web. However, Ecospace, the spatial-temporal module of EwE, traditionally has limited capacity to incorporate external environmental and anthropogenic spatially dynamic data, largely assuming static environmental conditions. Here we present three major advances that have recently been added to Ecospace to overcome these limitations.

First, we have successfully extended Ecospace with a habitat foraging capacity model. This determines the ability of species to feed across the Ecospace grid by considering multiple environmental factors other than traditional habitat. This new model offers the ability to drive foraging capacity from multiple physical, oceanographic and environmental factors such as depth, bottom type, temperature, salinity, oxygen concentrations, etc., which have cumulative impacts on the ability of functional groups to forage and their distributions, while taking the complex predator – prey relationships into account. This development bridges the gap between envelope environmental models and classic ecosystem food-web models, progressing towards the ability to predict changes in marine food-webs under scenarios of global change. Secondly, we have added a spatial-temporal data exchange framework to Ecospace via open sources GIS technology and common software development paradigms. This framework is modular and extensible, and enables dynamic integration of external spatial-temporal data patterns to dynamically drive ecological or environmental patterns to better represent the changing environment. The framework has been used to drive the Ecospace food-web dynamics of several case studies, and has demonstrated to greatly enhance the predictive capabilities of the food-web model to hind-cast ecosystem dynamics. Finally, as a logical step, we have connected the habitat foraging capacity model and the spatial temporal data framework, effectively creating an integrated and spatial-temporal dynamic species distribution and food-web model.

Beyond greatly extending the predictive capabilities of the EwE approach, these new developments are also intended to contribute to the discussion of ecological model driver standardization, the simplification of ecological model interoperability, and eventually,

Workshop 7: Approaches to predicting fish from physics

facilitating flexibility towards the construction of coveted yet elusive end-to-end models, needed to assess ecosystem dynamics including climatological, biochemical, food-web and socio-economic factors.

Keywords: Ecosystem modelling, end-to-end, Ecospace, model interoperability

Oral presentation

Inter-comparison of global fisheries and ecosystem models

Tittensor D.P., Eddy T., Huber V. and Lotze H.K.

Global fisheries provide a significant proportion of the world's food and protein requirements, while the ecosystems that underpin them deliver a wide range of services and benefits. Given the predicted anthropogenically-induced changes in climate, as well as in human population, socioeconomic pathway, and consumption patterns, there remains an urgent need to assess the consequences of differing scenarios of climate change and human development. Significant resources have gone into creating fisheries and ecosystem models, yet these are based on very heterogeneous sets of assumptions and intentions, from tightly-focussed to broad, from statistical to process-based, static and dynamic. The FISH-MIP project, as part of the ISI-MIP inter-sectoral model comparison project, aims to produce a protocol for common inputs to, and a framework for assessing outputs from, this wide range of models. Here we report on the set of models that are included in the global assessment, the challenges that we faced when developing a common protocol, the hierarchical structure that we have adopted, and proposed future plans and further ideas for refinement.

Keywords: Climate change, scenarios, ecosystem, fisheries models

Oral presentation

Workshop 8: Beyond 'Z': what modellers need and empiricists have to offer to better incorporate higher trophic levels and humans in end-to-end models

Conveners

- **Alistair Hobday**
Marine and Atmospheric Research, Commonwealth Scientific and Industrial Research Organisation
Hobart, Australia
alistair.hobday@csiro.au
- **Kevin Weng**
Pelagic Fisheries Research Program, University of Hawaii, Manoa
Honolulu, USA
kweng@hawaii.edu
- **Joel Llopiz**
Biology Department, Woods Hole Oceanographic Institution
Woods Hole, USA
jllopiz@whoi.edu

Description of the workshop

Marine ecosystem models can differ greatly, but often focus on productivity-driven relationships between a few broad groups such as nutrients, phytoplankton, zooplankton, and detritus. Other, much more elaborate models can, to various degrees, also include aspects related to physics, biogeochemistry, small and large nekton, top predators, and humans. However, such end-to-end models are only recently being developed, and the appropriate inclusion of higher trophic levels and humans in such models is understandably challenging. The IMBER regional programme CLIOTOP (Climate Impacts on Oceanic TOP Predators) would like to engage both the modeling community (biogeochemical and whole-ecosystem modelers) and the empiricists who study higher trophic levels, fisheries, and the socioeconomics of fisheries to outline the current state of our fields and the data that will be needed in the future to advance and parameterize large-scale marine ecosystem models. In addition to highlighting how empiricists can better contribute to the data needs of marine ecosystem modelers, we will focus on a subset of the following questions:

1. What model constructions can support realistic representations of high trophic levels and humans?
2. How are the various life stages (e.g. larval vs. adult) of upper trophic levels or human behavioral typologies accounted for in models?
3. Can higher trophic levels affect biogeochemical cycles?
4. What role do the mesopelagic micronekton play as an intermediate step between lower and higher trophic levels, and in overall energy pathways and biogeochemical cycles?

Workshop 8: Beyond 'Z'

5. How does exploitation and biodiversity loss impact biogeochemistry and food web structure?
6. How will physical, chemical, and biological changes affect the distribution and abundance of upper trophic levels and, thus, the feedback into the system?
7. How will such changes affect fisheries, economies and cultures?

The final set of questions will be selected following registrations of interest in the workshop, and question leaders nominated.

Workshop Programme

Oral Presentations

Monday 23 June 2014, 09:00-09:30

Room K1

Time	Presenter	Title
09:00-09:25		W3+W7+W8 Joint introduction (overview of the three workshops, and a few words from the organizers of the Fish Model Intercomparison Project, FishMIP)

Monday 23 June 2014, 09:30-10:30

Room D7

Time	Presenter	Title
09:30-10:00	Costa, Daniel	Seasonality in the free ranging energetics of bottlenose dolphins
10:00-10:30	Koslow, Tony	Meso- and epipelagic fishes in the southern California Current System, ecological interactions and oceanographic influences on abundance: how can we model them?

Monday 23 June 2014, 11:00-12:00

Room D7

Time	Presenter	Title
11:00-11:30	Lehodey, Patrick	Optimization and evaluation of a micronekton model with acoustic data
11:30-12:00	De Boissieu, Florian	Role of micronekton in pelagic ecosystems: new insights from integrated cruises in New Caledonia Coral Sea, Pacific Ocean and Mozambique Channel, Indian Ocean

Workshop 8: Beyond 'Z'

Monday 23 June 2014, 14:00-16:00

Room D7

Time	Presenter	Title
14:00-16:00	All	General discussion

Monday 23 June 2014, 16:30-17:00

Room D7

Time	Presenter	Title
16:30-17:00	All	Preparation of the W8 synthesis. Discussion on the preparation of a potential synthesis paper

Monday 23 June 2014, 17:00-18:30

Room K1

Time	Presenter	Title
17:00-18:30		W3+W7+W8 plenary synthesis (each workshop gives a ~20 minute summary, 30 minutes for open discussion)

Poster Presentations

Monday 23 June, 13:00-14:00, Poster Session for Workshops

ID	Presenter	Title
W8.P1	Karakitsios, Vasileios	Case studies of paleo-environmental perturbations' effect on fish distributions
W8.P2	Coll, Marta	Trophic niche of squids: Insights from isotopic data in marine systems worldwide

Case studies of palaeoenvironmental perturbations' effect on fish distributions

Agiadi K. and Karakitsios V.

Environmental variability determines fish distribution, migration and abundance both in the present as well as the past. The close link between climate and fish populations has been observed in modern times, from seasonal to centennial time scales. However, the effect of long-term environmental changes and variability is little known. New data on fish eastern Mediterranean palaeobiogeography shows that naturally-occurring changes in the past have repeatedly modified the fish distribution in this area. Two study cases are exemplified. The distribution of small pelagic fish, such as *Engraulis encrasicolus* and *Sardinella maderensis*, in the northeastern coast of Rhodes Island between 2-0.5 million years before present, is correlated to the palaeoenvironmental conditions. Anchovies became very abundant in this area during warm periods, and departed with climatic deterioration. The concurrent presence of *Aphia minuta* with *E. encrasicolus* would indicate SST between 13-16°C. On the other hand, sardines are favored recurring upwelling conditions. A more complex scenario may be postulated for the varying distribution of Gadidae in the Ionian Sea and the south Aegean Sea, over approximately the last 5 million years. *Gadiculus argenteus*, *G. labiatus*, *G. thori* and *Micromesistius poutassou* inhabit eastern Mediterranean waters from the Miocene onwards, each associate with a distinct palaeoenvironmental setting. The blue whiting is part of the deep-water assemblages. *G. labiatus* is an extinct species found regularly in the Miocene to Middle Pleistocene associations, occasionally coexisting with *G. argenteus*. Its distribution is considered subtropical at that time. The three cod species' basin-wide distributions, at the stratigraphic stage level of resolution, generally overlap. However the more detailed study reveals that, at the regional scale, their occurrence is linked to significant climatic shifts. Indeed, *G. labiatus* gradually relinquishes its niche to *G. argenteus*, clearly a response to the general climatic deterioration from the late Pliocene to the Middle Pleistocene. Meanwhile, during the colder Pleistocene intervals *G. thori* invades the Mediterranean Sea, from the northeastern Atlantic, displacing *G. argenteus*.

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALIS –UOA-“Messinian Salinity Crisis: the greatest Mediterranean environmental perturbation and its repercussions to the biota” MIS: 375405.

Keywords: paleobiogeography, eastern Mediterranean, anchovy, sardine, cod

Poster presentation

Role of Micronekton in pelagic ecosystems: new insights from integrated cruises in New Caledonia Coral Sea, Pacific Ocean and Mozambique Channel, Indian Ocean

Allain V. and Menkes C., presented by De Boissieu F.

Micronekton is composed of 2-20-cm fish, squids, crustaceans and gelatinous organisms. In pelagic ecosystems, they are found from the surface to 1000 m depth and large parts of the populations undertake daily vertical migration to feed at the surface at night and hide at depth during the day. They play a central role in the pelagic ecosystem being at the interface between environmental forcing (physico-chemical oceanography and primary production) which influence their distribution and abundance and exploited top predators such as tuna which prey on micronekton. Despite this important role, the micronekton is still poorly known. To fill this knowledge gap, we have conducted a series of scientific cruises dedicated to the study of the micronekton with acoustic survey and net sampling in two locations in the Indian (Mozambique Channel) and the Pacific Ocean (New Caledonia Coral Sea). Those areas located around 20°S host mesoscale features generated by interactions between the surrounding topography and the main current flows and inducing high variability in the oceanographic conditions. We examined and compared between the two sites the micronekton composition, its diversity, its vertical and horizontal distribution and its abundance in relation to environmental parameters. Spatial patterns linked to the main water masses were evidenced and allowed us to bring new insights on the functional role of micronekton in the food webs of pelagic ecosystems.

Keywords: micronekton, spatial distribution, oceanography, diversity

Oral presentation

Seasonality in the free ranging energetics of Bottlenose dolphins

Costa D.P., Worthy G., Wells R., Read A.J., Waples D., Scott M.D. and Irvine A.B.

Bioenergetics is an important tool to examine the response of animals in their ability to respond to environmental disturbance, whether it is human or natural. Here we report the variation in field metabolic rate of 14 bottlenose dolphins during the summer and winter over a two year period using the O-18 doubly labeled water method. Animals were studying in Sarasota Bay where they could be captured dosed with isotopes released and recaptured a short time later. Summer animals exhibited field metabolic rates 4.23 & 5.26 times greater than resting metabolic rate (S92, 5.24 W/kg; S93, 7.3 W/kg), whereas winter animals exhibited field metabolic rates 3.11 times resting (W93, 4.27 W/kg). Winter blubber layer was greater than in summer. While surprising the higher metabolic rates in summer implies increased metabolic costs associated with thermal regulation that may include increased costs of repair and rejuvenation of the skin, and or increased costs associated with dumping heat. Our results suggest that bottlenose dolphins have an energetically expensive lifestyle similar to sea lions and fur seals. An important implication of our results is that as environmental temperature increase bottlenose dolphins will have higher metabolic rates, requiring an increase prey intake. However, increases in water temperatures are usually associated with decreased primary production, which would result in lower food availability, just as the dolphins energy requirements are increasing.

Keywords: Bioenergetics, climate change, field metabolic rate

Oral presentation

Meso- and epipelagic fishes in the southern California Current System, ecological interactions and oceanographic influences on abundance: how can we model them?

Koslow J.A., Davison P., Lara Lopez A. and Ohman M.A.

Mesopelagic fishes are inadequately represented by most current ecosystem models of eastern boundary currents (EBC). First, conceptual models of EBCs tend to characterize these ecosystems as “wasp-waisted,” with the mid-trophic level dominated by one or two epipelagic planktivorous fish species (e.g. sardine, anchovy), whose variability drives the population dynamics of both their predators and prey. Fish are often added to NPZ models as a single compartment represented by an epipelagic fish planktivore. However, revised biomass estimates for mesopelagic fishes in the California Current indicate that the biomass of this diverse group, dominated by plankton feeders, is about an order of magnitude larger than the epipelagic fish planktivores in this EBC, and their prey consumption is about 2-3-fold higher. The wasp-waist paradigm should be abandoned; mesopelagic as well as epipelagic fishes need to be added to the next generation of ecosystem models that seeks to go beyond the limitations of current NPZ models.

Second, most simple ecological models assume equilibrium, steady state conditions. Such models are implicitly driven by the biological interactions among competitors and between predators and prey. These assumptions were tested with time series for planktivorous meso- and epipelagic fishes, their predators and prey from the CalCOFI ichthyoplankton data set for the California Current Ecosystem. Steady-state models predict negative correlations between competitors, such as key groups of planktivores. However, the abundance of migratory and non-migratory mesopelagic planktivores were positively correlated with each other as well as with several key pelagic planktivores (anchovy, hake, and two mackerel species), indicating predominantly bottom-up forcing of this EBC ecosystem and a strong violation of the equilibrium, steady-state assumption. The hypothesis of bottom-up ecosystem forcing was further supported by the common correlations of meso- and epipelagic fish abundance with key indices for the physical ocean environment: the Multivariate ENSO index (MEI) and the Pacific Decadal and North Pacific Gyre Oscillations. An index for the combined biomass of epipelagic and mesopelagic migratory planktivores was negatively correlated with the abundance of several key planktonic copepod and krill taxa, a possible indication of top-down forcing. But these correlations between planktivores and their prey appeared to arise instead from their opposite correlations with a common set of environmental drivers, rather than from their biological interactions. Steady-state models appear fundamentally inappropriate for modeling food web structure and dynamics in the California Current Ecosystem.

Keywords: mesopelagic, epipelagic, planktivores, California Current, ichthyoplankton

Oral presentation

Optimization and evaluation of a micronekton model with acoustic data

Lehodey P., Conchon A., Senina I., Domokos R., Calmettes B., Jouanno J., Hernandez O. and Kloser R.

Micronekton at the Mid-Trophic Level (MTL) of the pelagic food web is one of the less known components of the ocean ecosystem, despite that they are a major driver of the spatial dynamics of their predators, many of them being exploited species (e.g., tunas). One modeling approach has been developed to represent the spatial dynamics of several MTL functional groups driven by physical (temperature and currents) and biogeochemical (primary production, euphotic depth) variables. A key issue remains the parameterization of the energy transfer from the primary production to the functional groups. To optimize these parameters, in situ acoustic data providing indirect estimates of the micronekton biomass need to be assimilated in the model. We present the parameter optimization approach based on Maximum Likelihood Estimation with an illustration using a transect of acoustic backscatter at 38 kHz collected during scientific cruises north of Hawaii. A series of twin experiments conducted to test the behavior of the model suggested that a minimum of 200 observations over several time steps at the resolution of the model are needed to estimate the parameter values with a minimum error. Despite that this amount of data was not available from the Hawaiian transect, the optimization experiment based on these actual data improved the estimation of biomass ratios.

Keywords: Micronekton, Acoustic, Modeling, SEAPODYM, Model Optimization

Oral presentation

Trophic niche of squids: Insights from isotopic data in marine systems worldwide

Navarro J., Coll M., Somes C. and Olson R.J.

Cephalopods are an important prey resource for fishes, seabirds, and marine mammals, and are also voracious predators on crustaceans, fishes, squid and zooplankton. Because of their high feeding rates and abundance, squids have the potential to exert control on the recruitment of commercially important fishes. In this review, we synthesize the available information for two intrinsic markers ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ isotopic values) in squids for all oceans and several types of ecosystems to obtain a global view of the trophic niches of squids in marine ecosystems. In particular, we aimed to examine whether the trophic positions and trophic widths of squid species vary among oceans and ecosystem types. To correctly compare across systems, we adjusted squid $\delta^{15}\text{N}$ values for the isotopic variability of phytoplankton at the base of the food web provided by an ocean circulation-biogeochemistry-isotope model. Studies that focused on the trophic ecology of squids using isotopic techniques were few, and most of the information on squids was from studies on their predators. Our results showed that squids occupy a large range of trophic positions and exploit a large range of trophic resources, reflecting the versatility of their feeding behaviour and confirming conclusions from food-web models. Clear differences in both trophic position and trophic width were found among oceans and ecosystem types. The study also reinforces the importance of considering the natural variation in isotopic values when comparing the isotopic values of consumers inhabiting different ecosystems.

Keywords: squid trophic level nitrogen isotopes

Poster presentation

Workshop 9: Eastern Indian Ocean upwelling research initiative planning workshop phase 3: physical dynamics and ecosystem responses

Conveners

- **Yukio Masumoto**
Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology
Yokosuka, Japan
masumoto@jamstec.go.jp
- **Raleigh R. Hood**
Horn Point Laboratory, University of Maryland
Cambridge, USA
rhood@umces.edu
- **Weidong Yu**
Center for Ocean and Climate Research, First Institute of Oceanography
Qingdao, China
wdu@fio.org.cn
- **Nick D'Adamo**
Perth Regional Programme Office, Intergovernmental Oceanographic Commission
West Perth, Australia
nick.dadamo@bom.gov.au

Description of the workshop

Recent progress on the Indian Ocean Observing System (IndOOS) has significantly promoted the understanding of the monsoon-ocean interaction and the role of the ocean in climate variations over a wide spectrum of time scales from intra-seasonal to inter-decadal, with global relevance and also specific relevance to the constituency of the Indian Ocean Global Ocean Observing System Regional Alliance (IOGOOS). Stimulated by this basin-scale progress, a new endeavour towards developing an interdisciplinary Eastern Indian Ocean Upwelling (EIOU) research initiative, involving its dynamical characterization and related ecosystem impacts, has been identified as an emerging multidisciplinary research priority by the Indian Ocean Panel (IOP) (under CLIVAR, GOOS and IOGOOS) and the Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) program (under IOGOOS and IMBER). It will also be a key component of the planned 50th Anniversary Celebration of the International Indian Ocean Expedition (IIOE-2). Interdisciplinary upwelling research has been identified as a high priority within CLIVAR as well. EIOU, compared with the Western Indian Ocean Upwelling (WIOU), is much less observed and understood. The monsoon-forced essence associated with the EIOU also distinguishes it from upwelling in other basins. Therefore, it deserves urgent scientific attention given the critical role it plays in basin to global scale climate (for example, relating to the Indian Ocean Dipole) and marine ecosystem and fishery dynamics.

Workshop 9: Eastern Indian Ocean upwelling research initiative planning

This workshop will review the past research relevant to EIOU and EIOU-WIOU contrasts, existing gaps in observational requirements to understand EIOU, summarize the outcomes of intensive discussion from two EIOU-targeted workshops planned respectively in April and November 2013, finalize the EIOU science and observational plan, discuss and refine the EIOU working plan for 2015-2020 time frame and IIOE-2.

Workshop Programme

Oral Presentations

Monday 23 June, 09:00-10:30

Chairs: Weidong Yu and Raleigh Hood

Room K4

Time	Presenter	Title
09:00-09:10	Yu, Weidong; Hood, Raleigh; Masumoto, Yukio; D'Adamo, Nick	Background briefing
09:10-09:30	Hood, Raleigh	The 50 th anniversary of the international Indian Ocean expedition: an update on current planning efforts and progress
09:30-09:50	Masumoto, Yukio	Interactions between intraseasonal and interannual variability in the upwelling region off Sumatra during onset of the 2006 IOD
09:50-10:10	Yu, Weidong	Eddy activities in the Southeastern Indian Ocean
10:10-10:30	Ueki, Iwoa	Eastern Indian Upwelling related studies in JAMSTEC

Monday 25 June, 11:00-12:30

Chairs: Weidong Yu and Raleigh Hood

Room K4

Time	Presenter	Title
11:00-11:20	Ji, Rubao	Plankton distributions off Java during the SE monsoon
11:20-11:40	Visbeck, Martin	Marine science in support for sustainable development of the Indian Ocean Region
11:40-12:00	Hardman-Mountford, Nick	Using biogeochemical models to optimize sampling design for biogeochemical profiling float arrays
12:00-12:30	Valliyodan, Sudheesh	Factors controlling N ₂ O saturation and fluxes from the continental shelf waters of southeastern Arabian Sea: A time-series study

Workshop 9: Eastern Indian Ocean upwelling research initiative planning

Monday 25 June, 14:30-16:00

Chairs: Yukio Masumoto, Nick D'Adamo

Room K4

Time	Presenter	Title
14:30-15:10	Yu, Weidong	Introduction of EIOURI Science Plan and Implementation Strategy (SPIS)
15:10-15:40	Masumoto, Yukio	Group Discussion on physical part of EIOURI SPIS
15:30-16:00	Hood, Raleigh	Group Discussion on biological / chemical / ecosystem part of EIOURI SPIS

Monday 25 June, 16:30-17:30

Chairs: Yukio Masumoto, Nick D'Adamo

Room K4

Time	Presenter	Title
16:30-17:00	Yu, Weidong	Discussion on cruise coordination
17:00-17:30	D'Adamo, Nick	Wrap-up and next step actions

Poster Presentations

Monday 25 June, 13:30-14:30

Chair: Yukio Masumoto

ID	Presenter	Title
W9.1	Yi, Xing	Impact of large-scale climate patterns on the western Arabian Sea coastal upwelling system

Using biogeochemical models to optimize sampling design for biogeochemical profiling float arrays

Hardman-Mountford N., Greenwood J., Dufois F. and Trull T.

Bio-optical and chemical sensors on profiling floats promise great potential for observing the biogeochemistry of the interior ocean. However, resolving the relevant space-time modes of variability for biogeochemical processes requires different sampling strategies and mission configurations than are used for standard Argo floats. As part of an Australia-India Strategic Research Fund project, a number of floats equipped with biological sensors will be deployed in a region of interest in the Indian Ocean, yet to be determined. Deployment opportunities have been identified in the SE Indian Ocean, Indonesian through-flow region, within the Indonesian upwelling/oxygen minimum zone, and in the Bay of Bengal. In each case, the biogeochemical questions addressed and sampling approach are expected to be different. To optimize the sampling design for the placement and configuration of the floats, a particle-tracking model has been employed to simulate the trajectories of profiling floats. The simulated float trajectories are used to sample biological and chemical fields, from existing data streams, to assess the accuracy with which these fields can be reconstructed from the float data, and how well the biogeochemical features of interest can be resolved.

Keywords: Bio-Argo, Indian Ocean, oxygen, upwelling, eddies

Oral presentation

The 50th anniversary of the International Indian Ocean Expedition: An update on current planning efforts and progress

Hood R. and D'Adamo N.

The International Indian Ocean Expedition (IIOE) was one of the greatest international, interdisciplinary oceanographic research efforts of all time. Planning for the IIOE began in 1959 and the project officially continued through 1965, with 46 research vessels participating under fourteen different flags. The IIOE motivated an unprecedented number of hydrographic surveys (and repeat surveys) over the course of the expedition covering the entire Indian Ocean basin. And it was an interdisciplinary endeavor that embraced physical oceanography, chemical oceanography, meteorology, marine biology, marine geology and geophysics.

The end of 2015 will mark the 50th Anniversary of the completion of the IIOE. In the 50 years since the IIOE three fundamental changes have taken place in ocean science. The first is the deployment of a broad suite of oceanographic sensors on satellites that have dramatically improved the characterization of both physical and biological oceanographic variability. The second is the emergence of new components of the ocean observing system, most notably remote sensing and Argo floats. And the third is the development of ocean modeling in all its facets from short-term forecasting to seasonal prediction to climate projections. These advances have revolutionized our understanding of the global oceans, including the Indian Ocean. Compared to the IIOE era, we now have the capacity to provide a much more integrated picture of the Indian Ocean, especially if these new technologies can be combined with targeted and well-coordinated in situ measurements.

In this presentation we report on current efforts to motivate an IIOE 50th Anniversary Celebration (IIOE-2). We envision this IIOE-2 as a 5-year expedition and effort beginning in 2015 and continuing through to 2020. An important objective of our planning efforts is assessing on-going and planned research activities in the Indian Ocean in the 2015 to 2020 time frame, with the goal of embracing and helping to organize these activities as part of a larger coordinated 50th Anniversary research initiative. In addition we are working to motivate conferences, summer schools, repeat line work and new process studies.

Keywords: Indian Ocean, Expedition, IIOE

Oral presentation

Interactions between intraseasonal and interannual variability in the upwelling region off Sumatra during onset of the 2006 IOD

Masumoto Y.

Subsurface temperature variability in the southeastern tropical Indian Ocean associated with the 2006 Indian Ocean Dipole (IOD) event and a possible mechanism responsible for cooling of the upper-ocean during a generation period of the IOD are investigated using satellite data, atmospheric reanalysis data, and results from a high-resolution ocean general circulation model (OFES). OFES reproduced the 2006 IOD event realistically in terms of time evolution of the subsurface temperature in the eastern tropical Indian Ocean. During May to July 2006, prior to the emergence of the surface IOD signals, several equatorial upwelling Kelvin waves are excited in the central Indian Ocean by zonal wind stress anomalies. These Kelvin waves penetrate into the coastal regions along the Sumatra and Java Islands, and generate subsurface negative temperature anomalies through a vertical advection term in the heat budget analysis. It turns out that the vertical advection term is dominated by a term associated with an advection of mean vertical temperature gradient by an anomalous vertical velocity. These subsurface cooling processes associated with the intraseasonal Kelvin waves seem to be important for the onset of the sea surface temperature anomaly off the coast of Sumatra and Java Islands in 2006.

Keywords: Upwelling, Sumatra, IOD, Intraseasonal variations

Oral presentation

Factors controlling N₂O saturation and fluxes from the continental shelf waters of southeastern Arabian Sea: A time-series study

Sudheesh V., Sudharma K.V. and Gupta G.V.M.

Western continental shelf of India is recognized as a 'hotspot' for nitrous oxide (N₂O) as a result of upwelling associated seasonal anoxia/suboxia, their effluxes from upwelled coastal waters of southeastern Arabian Sea (SEAS) remains poorly characterized. Monthly observations in the shelf waters of Cochin, SEAS during April-December 2012 showed significant variability in supersaturation of N₂O influenced by strong denitrification activity during summer monsoon (SM) upwelling (June-September) and less intense nitrification in winter monsoon (WM) downwelling (November-January), apart from anthropogenic inputs. The surface saturation recorded a maximum of 2653% during June. The average N₂O saturation was highest during SM (574±720%) compared to fall inter monsoon (246±76%), WM (140±12%) and spring inter monsoon (123±12%). The N₂O fluxes varied between 0.29-467 μmol m⁻² d⁻¹ with maximum recorded during SM (108±132 μmol m⁻² d⁻¹). The N₂O production increased exponentially when dissolved oxygen concentration fall below 25 μM during SM upwelling as the denitrification process turned on. A comparison of N₂O concentrations between off Cochin (10°N) and off Mangalore (12.8°N) showed that latter region recorded higher concentrations (73±63 nM) associated with anoxic conditions compared to former region (45±32 nM) during SM. During September, the inner shelf waters of Mangalore exhibited low concentrations of oxidized nitrogen species (NO₃⁻, NO₂⁻, N₂O) coinciding with high accumulation of NH₄⁺ and H₂S possibly due to dissimilarity in nitrate reduction to ammonium (DNRA). Despite the shelf waters of Mangalore are anoxic, they showed distinctly demarcated processes viz. sulfate reduction in the near shore, DNRA in the inner shelf, intense denitrification in the mid-shelf and relatively less denitrification in the outer shelf. Whereas the Cochin shelf waters did show only denitrification as they are suboxic/hypoxic. This regional difference within the SEAS appears to indicate the strong influence of corresponding offshore oxygen minimum zone magnitude and extension of these watermasses as upwelled waters into the shelf waters.

Keywords: Nitrous oxide, Denitrification, Upwelling, Anoxia, Southeastern Arabian Sea, Time-series

Oral presentation

Eastern Indian Upwelling related studies in JAMSTEC

Ueki I., Ando K., Horii T. and Masumoto Y.

To capture the Indian Ocean dipole (IOD) related features in the southeastern tropical Indian Ocean (SETIO), triangle trans-ocean buoy network (TRITON) moorings were deployed from October 2001. Time series of upper ocean parameters and sea surface fluxes observed with these moorings revealed heat balance within the ocean mixed layer at the eastern pole of IOD. During the positive IOD events, westward cold anomaly advection from east became dominant at the region suggesting importance of off-Sumatra upwelling. Unfortunately we do not have enough observation, which can resolve variability of off-Sumatra upwelling. We need more information of ocean condition near coastal region to study about mechanism for IOD development. We also have another research target in the SETIO, which is phytoplankton bloom associated with off-Java meso-scale eddies. In addition to seasonal coastal bloom along the Java coast, off-shore bloom also appeared and enhanced during the positive IOD year. Although the off-shore blooms were identified by satellite observation, we do not have underwater condition including water property change. To the purpose of advancing these studies, we are planning to in situ observation by research vessel and moorings. We will introduce progress of our plan, which will be associated with the eastern Indian Ocean upwelling research initiative.

Keywords: Eastern Indian Ocean, IOD, upwelling

Oral presentation

Marine science in support for sustainable development of the Indian Ocean Region

Visbeck M. and Bange H.W.

The Indian Ocean rim is home to a significant part of the global population. Its large heat capacity and ocean circulation responds to and regulates seasonal to multi-decadal and long term climate change. In particular the monsoon type circulation regulates rain and drought patterns over India, Africa and Southern Asia. Fishing and more recently resource extraction of energy and materials make the ocean economically important. Global trade and ocean related hazards (such as ocean warming, ocean acidification, ocean de-oxygenation, loss of biodiversity, sea level rise and earth quakes and tsunamis) have important other economic impacts on all societies. On the other hand our current scientific understanding, ability to continually observe changes in the marine environment, model all aspects of the connected ocean system and develop plausible scenarios for the Indian Ocean of the future are still in its infancy. The possibility for a decade long comprehensive Indian Ocean Study in support of providing the information needed for sustainable development of the region is explored.

Keywords: Indian Ocean

Oral presentation

Impact of large-scale climate patterns on the western Arabian Sea coastal upwelling system

Yi X., Zorita E. and Hünicke B.

The understanding of the causes of variability and trends in upwelling dynamics is relevant to assess the influence of climate change on the productivity of upwelling systems. In this contribution we aim to characterize the large-scale climate forcing that drive the upwelling along the coast of the western Arabian Sea. For this purpose, we analyse an eddy-resolving global ocean simulation with the model MPI-OM over the period 1948-2010 (STORM). The ocean model was hereby driven by the 6-hourly global NCEP meteorological reanalysis data. The number of horizontal grid points (3602 x 2394) with a distance of approximately 10km allows identifying the characteristics of the western Arabian Sea coastal upwelling system and its response to other oceanic variables at local, regional and global scales. As in the observations, the upwelling starts in May and lasts until the end of September, during which time the Indian southwest (SW) monsoon acts as a dominating factor controlling this upwelling system. The Indian monsoon reverses its wind direction during winter and summer time. In this study we analyse the co-variability between upwelling, defined as the vertical near-coast mass transport, and other modelled oceanic and meteorological variables, such as sea-surface temperature from the STORM-simulation together with sea-level pressure and wind stress data (NCEP) and precipitation data (GPCC) for the time period 1948-2010. The analysis of the temporal and spatial variation over 61 years (1950-2010) demonstrates that wind stress has been an important indicator to the upwelling system (with a correlation coefficient of 0.85 in the upwelling season). The intensity of upwelling is also associated with the off-shore spatial gradient of the sea-surface temperature. Contrary to the expectation contained in the hypothesis put forward by Bakun (1990), there is no detectable long-term trend either in the intensity of upwelling or in the regional wind-stress.

Bakun, A.: Global climate change and intensification of coastal ocean upwelling. *Science*, 247, 198–201, 1990.

Keywords: upwelling, monsoon, STORM, large-scale climate patterns

Poster presentation

Eddy activities in the southeastern Indian Ocean

Yu W. and Yang G.

The Eastern Indian Ocean upwelling along the Java and Sumatra is an important seasonal process that brings rich nutrients from the deep ocean to the surface and hence supports the ecosystem in the coastal and nearby open ocean region. This upwelling system involves complex physical-biological interaction with high potential in fishery sustainability and hence is prioritized as the key topic of the Eastern Indian Ocean Upwelling Research Initiative (EIOURI). The linkage between the rich coast and oligotrophic open-ocean urgently deserves deep understanding. Usually this linkage is established through the mean circulation, like the South Equatorial Current (SEC) and Indonesia Throughflow (ITF), and the eddy processes. Although the circulation pattern in the southeastern Indian Ocean is becoming more and clearer, the eddy processes still need further exploration. Based on the satellite altimeter data, Argo profiles, the satellite ocean color data, and the satellite SST data, the eddy activities in the southeastern Indian Ocean is documented. Along with the previous understanding of the strong eddy activities near the SEC fronts, particularly interesting, another eddy active region is identified along the southern south Java, close to the Lombok strait. The cyclonic/anti-cyclonic eddy from this region exhibits the southwestern/northwestern propagation and brings the upwelling information to the open ocean. The composite maps of surface chlorophyll-a, SST and vertical T/S structure of the eddy are illustrated. These preliminary eddy results also help guide the planning and implementing of EIOURI.

Keywords: eddy, upwelling, Eastern Indian Ocean, nutrients

Oral presentation

Workshop 10: Surface Ocean CO₂ Atlas (SOCAT)

Community Event

Conveners

- **Dorothee Bakker**
Centre for Ocean and Atmospheric Sciences, School of Environmental Sciences,
University of East Anglia
AngliaNorwich, UK
d.bakker@uea.ac.uk
- **Are Olsen**
Geophysical Institute, University of Bergen
Bergen, Norway
are.olsen@gfi.uib.no
- **Bronte Tilbrook**
Marine and Atmospheric Research Division, Commonwealth Scientific and Industrial
Research Organisation (CSIRO)
Hobart, Australia
bronte.tilbrook@csiro.au
- **Simone Alin**
Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric
Administration (NOAA)
Seattle, USA
simone.r.alin@noaa.gov
- **Kevin O'Brien**
Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric
Administration (NOAA)
Seattle, USA
kevin.m.o'brien@noaa.gov
- **Maciej Telszewski**
International Ocean Carbon Coordination Project (IOCCP), Institute of Oceanology,
Polish Academy of Sciences
Sopot, Poland
m.telszewski@ioccp.org

Description of the workshop

The Surface Ocean CO₂ Atlas (SOCAT) is an activity by the international marine carbon research community. It aims to improve access to surface water CO₂ data by regular releases of quality controlled, synthesis and gridded *f*CO₂ (fugacity of carbon dioxide, similar to partial pressure) data products for the global oceans and coastal seas. SOCAT version 2, public since June 2013, contains 10.1 million surface water *f*CO₂ data from 2660 data sets between 1968 and 2011. Version 3 extends the data set to December 2013 and includes CO₂ measurements from alternative sensors and platforms. Quality control for version 3 will be carried out in

Workshop 10: Surface Ocean CO₂ Atlas (SOCAT)

summer 2014. The automation system for data submission (for version 4) will be launched in 2014.

Key questions to be addressed include:

- What is needed for efficient quality control (version 3)?
- How does data submission via the automation system work?
- Should SOCAT products include additional parameters (version 4)?
- How do we promote SOCAT science?

The workshop will update the SOCAT community on recent progress, will welcome new members, will enable discussion of SOCAT strategy and will set the SOCAT agenda for the next 24 months. The workshop will contribute to efficient quality control and submission via the automated data submission system. The workshop will provide feedback on SOCAT strategy to the global and regional leads.

Workshop Programme

Oral Presentations

Monday 23 June, 09:00-10:30

Chair: Bronte Tilbrook

Room D8

Time	Presenter	Title
09:00-09:15	Dorothee Bakker	Introduction and Aims of the Community Event
SOCAT version 3 quality control Session leads: Rik Wanninkhof, Ute Schuster, Are Olsen		
09:15-09:30	Benjamin Pfeil, Karl Smith, Kevin O'Brien	Update on version 3
09:30-09:45	Dorothee Bakker	Version 3 time table
09:45-10:00	Rik Wanninkhof	Quality control of the Surface Ocean CO ₂ Atlas (SOCAT) version 3 data: Revised quality control flags in version 3
10:00-10:15	Ute Schuster	Planned quality control for version 3 in practice
10:15-10:30	All	General Discussion

Monday 23 June, 11:00-12:30

Chair: Kim Currie

10:15

Time	Presenter	Title
SOCAT version 3 quality control (continued)		
11:00-11:30	Rik Wanninkhof, Are Olsen, Dorothee Bakker	Other issues (sea surface temperature, WOCE flags, quality salinity and cut-off on landside in synthesis products)
Automation for version 4 Session leads: Kevin O'Brien, Steve Jones		
11:30-12:00	Kevin O'Brien, Steve Jones, Karl Smith	SOCAT version 4 automation: Data submission via the automation system

Workshop 10: Surface Ocean Co₂ Atlas (SOCAT)

Monday 23 June, 13:00-14:30

Room D8

Time	Presenter	Title
Demonstrations, Discussions and Break-out groups		
13:00-13:45	Ute Schuster	Demonstration / Discussion of version 3 quality control
13:45-14:30	Karl Smith, Kevin O'Brien, Steve Jones	Demonstration / Discussion of automated data submission

Monday 23 June, 14:30-16:00

Chair: Ute Schuster

Room D8

Time	Presenter	Title
Future SOCAT		
Session leads: Dorothee Bakker, Are Olsen, Maciej Telszewski		
14:30-15:00	All	Science highlights from regional leads and key participants (2 slides each)
15:00-15:30	Are Olsen	Addition of extra parameters in version 4 or later?
15:00-16:00	Rik Wanninkhof	Acknowledgments and credits for data providers

Monday 23 June, 16:30-18:30

Chair: Colm Sweeney

Room D8

Time	Presenter	Title
Future SOCAT (continued)		
16:30-17:15	Corinne Le Quéré <i>via WebEx</i> , Steve Jones	SOCAT and the Global Carbon Project
17:15-17:45	Maciej Telszewski	Measure success of SOCAT
17:45-18:15	Dorothee Bakker	Future SOCAT: Plans for SOCAT science
18:15-18:30	Dorothee Bakker	Conclusion

Future SOCAT: Plans for SOCAT science

Bakker D., Le Quéré C., Olsen A. and Telszewski M.

The Surface Ocean CO₂ Atlas (SOCAT) requires input from the SOCAT community on its future direction. This session allows the community to discuss opportunities and challenges for SOCAT. Topics for discussion include: 1) Measuring the success of SOCAT, 2) Collaboration between SOCAT and the Global Carbon Project (GCP), 3) The inclusion of additional parameters and 4) Plans for SOCAT science. Additional topics may be added over the coming months, as they arise.

1) Measuring the success of SOCAT: How can we quantify the impact of the SOCAT community effort? Is data more available thanks to SOCAT? Has the use of SOCAT improved the latest GCP budget? Are models improved? Are decisions more informed? Is society better informed? Do we reach out to various communities and can we measure the value of this outreach? Should SOCAT develop some sort of success indices? This kind of information is important when discussing the surface ocean observing system as a whole. If we can quantify the usefulness of SOCAT, we can use it to justify the need for a (sustained and improved) observation network, and the need for instrument development.

2) Collaboration between SOCAT and the GCP: For its Global Carbon Budgets the GCP would like early access to the most recent one or two years of data submitted to SOCAT. For these recent data the GCP team will use recalculated fCO₂ data in a uniform format, but without the full SOCAT quality control. Providers of the recent data will be invited as contributors of that year's budget. Contributors of data that is not yet public will be consulted by the GCP prior to the use of their data. The collaboration between SOCAT and the GCP will be discussed.

3) The inclusion of additional parameters in SOCAT: Frequent requests are made to add extra parameters to SOCAT, e.g. atmospheric carbon dioxide and surface water nutrients, dissolved inorganic carbon, alkalinity, methane and nitrous oxide. At present additional parameters submitted to SOCAT are archived, but they are not quality controlled (QC-ed) and not included in the SOCAT data products. Regional leads have agreed to only include parameters in SOCAT which have been quality controlled. SOCAT regional leads have major concerns on the extra QC effort required for the inclusion of additional parameters. An alternative would be to make extra parameters available in separate data products with independent time lines, while using the SOCAT archive and infrastructure. Such an initiative would require several champions.

4) Plans for SOCAT science: SOCAT data products and tools have multiple applications, notably: Quantification of the ocean carbon sink and its variation; Studies of ocean carbon cycling and ocean acidification; Initialisation and validation of ocean carbon cycle models; Constraints for atmospheric inverse models for global carbon budgets. This discussion will focus on how we can promote SOCAT science.

Keywords: Future SOCAT challenges science GCP success

Oral presentation

SOCAT version 4 automation: Data submission via the automation system

O'Brien K. and Hankin S.

A lesson made clear after the completion of SOCAT versions 1 and 2 was that the process for incorporating new data, uniformly assessing quality, and releasing new versions of the collection is too labour intensive to sustain. A plan for 'automation' was therefore agreed upon, which will streamline the process to the maximum degree feasible.

In this session, we will discuss the advances in the SOCAT system that has been designed to automate the various SOCAT processes. Beginning with version 4, the manual responsibilities of the SOCAT data curators will be replaced to the degree feasible with Web-based functions. Through the automation process, scientists will be able to upload their data directly into the SOCAT QC system. As part of the upload, an automated 'sanity check' will be run to find obvious errors in the data being uploaded, and data uploaders will be able to access visualizations of their data to identify and correct issues in the data. The automation system will also provide tools so that the scientists or principal investigators can inform the system about the parameters and units that exist in their uploaded files. As part of the automation process, standardized metadata will be required, and web tools for entering, editing, and error checking metadata will be provided.

This session will provide a demonstration of the system, from submission of data through QC and data archival. We will also be soliciting feedback on ways to improve the system.

Keywords: SOCAT, carbon, QC, automation

Oral presentation

Quality control of the Surface Ocean CO₂ Atlas (SOCAT) version 3 data: Revised quality control flags in version 3

Wanninkhof R., Schuster U., Alin S. and Olsen A.

In this session we will present the current secondary quality control (QC) process of the Surface Ocean CO₂ Atlas, SOCAT, and seek audience input on what level of quality is required for different uses of SOCAT, such as quantification of sea-air CO₂ fluxes on various time and space scales, patterns of ocean acidification, and extrapolation of laboratory and mesocosm findings on the effects of ocean acidification. The venue aims to widen the uses of SOCAT and solicit feedback on current secondary QC, in particular how to include new sensors, how the QC flags are used in creating data products, and other applications. We will also encourage more groups to become involved the community-based secondary QC efforts.

The value of SOCAT lies in its vast holdings with more than 10 million unique surface water fugacity of CO₂, fCO₂ values; uniform format; ease of access; its derived data products and a quantifiable quality estimate of the data. Since absolute accuracy determinations are problematic for fCO₂ measurements in part due to lack of liquid fCO₂ standards, other means are developed to provide an assessment of quality. This relies on metadata of sufficient detail to determine the instrument characteristics, a consistent data reduction scheme, and a secondary QC step. In secondary QC the submitted data-set is reviewed in context of specific metrics relating to environment, instrument, completeness of metadata, and neighboring cruises. The secondary quality control is thus largely based on instrumental requirements and provides a letter code for each data-set, determined by a prescribed protocol. The letter code (A-E) is based on the type of instrument and calibration procedure as described in the accompanying metadata using standardized metadata forms. For version 3 of SOCAT the letter codes are adapted to include a semi-quantitative estimate of uncertainty of the measurements in the data-set. Version 3 will also include a data-set quality code for a new generation of sensors whose accuracy is difficult to estimate with current procedures. The accuracy estimates are based on side-by-side comparisons of instruments in both laboratory settings such as multi-national comparison efforts, and in the field by deploying several instruments on the same platform. In the secondary QC process, comparison of data in the same location and time span determined from a time-space correlation estimate are a significant component. However, the agreement is relatively lax because of known small-scale variability. Secondary QC is an important and evolving process that relies on community input for execution and improvement.

Keywords: SOCAT, Surface Ocean CO₂, Quality Control

Oral presentation

Plenary Sessions and Talks

Tuesday 24 June, 08:30-10:30

Gruber N. et al.

Warming up, turning sour, losing breath: The regional perspective

Liu K.K.

Anthropogenic impacts on biogeochemical processes and ecosystems in continental margins: lessons learned from cases around the globe and future perspective

Wednesday 25 June, 08:45-10:30

Moloney C.L.

Food webs and biogeochemistry in a changing marine environment

Gattuso J.P.

Drivers of, and responses to, ocean acidification

Thursday 26 June, 08:45-10:15 & 16:00-17:30

Bundy A.

Dead ends and grasping hands: failed governance and the need to integrate human-ocean interactions into global change science

Le Quéré C.

From CO₂ surveys, nutrient budgets, ecosystem process studies and modelling, to the Future Earth era: preserving our strengths and shaping new opportunities for the IMBER community

Friday 27 June, 08:45-10:00 & 12:15-13:15

Campagna C. et al.

Species and spaces in the ocean: From sustainability to conservation

Hobday A.

Climate change impacts and adaptation options for high trophic level marine species

Warming up, turning sour, losing breath: The regional perspective

Gruber N., Lachkar Z., Münnich M., Franco-Novela A.C., Frölicher T., and Turi G.

Although ocean warming, ocean acidification, and deoxygenation are global stressors, their impact on oceanic ecosystems and biogeochemistry occurs at the regional to local scale. Among the potentially most vulnerable marine ecosystems are the eastern boundary upwelling regions, as they are exceptionally productive, but also prone to be among the first oceanographic regions to cross critical thresholds. Among the most important ones are the oxic to suboxic transition, or the appearance of wide-spread undersaturated conditions with regard to the mineral CaCO_3 . Of special concern is the projected co-occurrence of these stressors in the coastal systems, potentially aggravated (or ameliorated) by climate-change induced circulation changes, such as increased upwelling. In this plenary presentation, we provide an overview of the local to regional manifestations of the potential future evolution of these stressors using eddy-resolving regional simulations for the California, Canary, and Humboldt Current systems. We will be using idealized as well as more realistic scenarios to exploit the potential future biogeochemical/physical states in these systems and how this regional focus contrasts with global-scale assessments. In general, we will show that in the regional scale the critical thresholds are projected to be crossed much earlier than global models suggest, i.e., that the niches for many organisms in these eastern boundary regions may be changing more rapidly than anticipated. While this finding holds across the three systems investigated, important differences are found between them, especially with regard to deoxygenation. Assessing the full impact of the simultaneous action of the three stressors on marine organisms and ecosystems is presently not yet possible, highlighting the need for coordinated research on multiple stressors in the marine environment.

Keywords: Multiple stressors, deoxygenation, Ocean acidification, warming

Anthropogenic impacts on biogeochemical processes and ecosystems in continental margins: lessons learned from cases around the globe and future perspective

Liu K.K.

More than 1/3 of the global human population resides within 100 km from the coast, asserting an increasing pressure on the ecosystems in continental margins, which include continental shelves, boundary current systems and marginal seas. Besides direct human impacts, continental margins are probably most vulnerable to impacts from climate change resulting from either natural oscillation or human induced changes. On the other hand, the ecosystem services and goods provided by continental margins are crucial to the survival of mankind. More than 90% of natural and farmed fish production is supported by the continental margin ecosystems, thus serving as an important food source. Increasingly, offshore uses are diversifying and intensifying, and thus create a need for risk and benefit assessments as exemplified by the Deepwater Horizon oil spill in the Gulf of Mexico. Continental margins in the western North Pacific also serves as an outstanding example of anthropogenic impacts on the marine ecosystems and biogeochemical pathways by the 3 fold increase in nutrient loading in the past 4 decades. A recent numerical experiment demonstrates the non-linear increase of intense sediment oxygen consumption in the East China Sea off the Yangtze River mouth and the frequent reports of hypoxia events in the past two decades. Emerging evidence indicates that the hydrological cycle is accelerating through the ocean-atmosphere-land system, probably as a result of global warming, which implies increases in river runoff with time. These changes will alter carbon cycling and related biogeochemical processes on continental margins of the global scale. We need to understand the linear and non-linear responses of biogeochemical and ecological processes to such drivers, because sound policies and effective management must be based on good understanding of how margin ecosystems function and their interaction with the biogeochemical cycles.

Keywords: anthropogenic impacts, continental margins, ecosystems, biogeochemistry

Food webs and biogeochemistry in a changing marine environment

Moloney C.L.

One of the key challenges for IMBER at its inception was to understand how biogeochemical cycles and food webs interact in the oceans. The different processes influencing the storage of material in living and non-living forms and its transformation between inorganic and organic states needed to be quantified, within and across systems. One of the main tools to accomplish this has been the use of coupled models. During this time, new research areas became prominent in marine global change research. Some of these include the identification of new metabolic pathways, the emerging role of ocean acidification, a new emphasis on microbial groups such as viruses and archaea, and renewed interest in previously neglected trophic processes like mixotrophy and parasitism. This presentation aims to describe some approaches that have been adopted in modelling marine biogeochemistry and food webs. It will address the questions being asked of the models and try to provide answers to some of these. In the process, it aims to identify current gaps in understanding and possible ways forward.

Keywords: biogeochemistry, marine food webs, models

Drivers of, and responses to, ocean acidification

Gattuso J.P.

Anthropogenic ocean acidification and global warming share the same primary cause which is the increase of atmospheric CO₂. Eutrophication, loss of sea ice, upwelling and deposition of atmospheric nitrogen and sulphur all exacerbate ocean acidification locally. Ocean acidification has emerged over the last two decades as one of the threats to marine organisms and ecosystems. The rate of publication has considerably increased in recent years. I will first briefly review the current knowledge based on recent meta-analyses, reviews, and assessments. The effects on the past, present and future carbonate chemistry are known with a high degree of certainty. Most biological and ecological effects are much less certain although there is little doubt that calcification, primary production and nitrogen fixation, and biodiversity will be altered but with an unknown magnitude. These changes will in turn generate changes in the biogeochemical cycles, society and the economy. Whether these changes will be significant or not is also unknown. I will also highlight key unknowns and research gaps, and provide a very brief account on how IMBER helped to build up a strong community of "ocean acidification scientists".

Dead ends and grasping hands: failed governance and the need to integrate human-ocean interactions into global change science

Bundy A.

Global environmental change brings new challenges to old problems regarding marine resources, resource dependent communities and their governance. Ocean ecosystems are dynamic, in a state of continual change and have traditionally been considered vast, inexhaustible resources. In parallel, humans are intimately connected to the ocean as users of their “services”, drivers of change and consequently, “beneficiaries” of the impacts of change. As globalizing processes have increasingly resulted in a neo-liberal capitalist model of operation, change in the world’s oceans has accelerated in concerning ways, often with consequences far beyond those anticipated. Fisheries exploitation has already altered the size and trophic structure of marine biotic communities causing deleterious, perhaps irreversible change; the oceans are warming up, becoming more acidic, more eutrophic (in coastal areas), sea levels are rising, there is increased flooding, droughts and increased in frequency and intensity of extreme weather events; human communities and organisations are losing livelihoods, traditional ways of being and self-determination. To date, when the major threat to ocean ecosystems has been fisheries over-exploitation, we have essentially failed to use science advice to manage ocean use for healthy, productive ecosystems; now, we have the additional threat of the consequences of climate change. Clearly there needs to be change in the way we provide science advice, in the way that advice is used and in the way that our ocean ecosystems are governed. There is a complex set of interactions, at multiple levels, between the natural, social and governing systems. In order to address the challenge of reconciling human use of the oceans and global change we need to develop understanding of these interactions, their key drivers, impacts and responses. Approaches must necessarily be inter- and transdisciplinary, from local to global and at multiple scales. However there are still major disconnects between natural and social sciences, science and policy, and public perception of global change, its causes and the “reality” of change. This presentation will touch on some of the areas that IMBER has already begun to explore regarding integrating human-ocean interactions into its broader science and address the larger question concerning what IMBER could and should focus on in the future. What research is required to understand and sustain marine resources and their dependent human communities? What is the need for and attributes of interdisciplinary research approaches required to address the issues? How can we ensure that this research is useful?

From CO₂ surveys, nutrient budgets, ecosystem process studies and modelling, to the Future Earth era: preserving our strengths and shaping new opportunities for the IMBER community

Le Quéré C.

Future Earth is a new international research initiative that aims to develop the knowledge for responding effectively to the risks and opportunities of global environmental change and for supporting transformation towards global sustainability in the coming decades. Future Earth builds on the strengths of existing programmes, but aims to push interdisciplinarity to a new level by bringing together the full spectrum of global environmental change research from natural to social sciences, humanities and engineering, and by fostering closer interactions with the Stakeholders of research.

This presentation will highlight a few areas and activities where the IMBER community is particularly well placed to shape Future Earth by addressing the big global change questions in the marine environment, for example, by developing our understanding of carbon and nutrient balance, and how the ecosystems can be managed, new methods to access, review and integrate large environmental and socio-economic data to support the monitoring of the marine environmental status and the delivery of societal goals (e.g. the Sustainable Development Goals), and by developing and using models at all scales that capture the dynamics of human-ocean interactions and lead to better risk management and healthier ecosystem resources and services in the marine environment.

Species and spaces in the ocean: From sustainability to conservation

Campagna C. and Costa D.

The 1980s initiated the era of sustainable development and the 2000s that of the Anthropocene. During both periods, the leading perspective was that the world should be the way humans want and need it to be. Science is affected by these visions. While scientists are actively injecting new information and concepts into the structure of ecological knowledge, including threats to biodiversity and habitats, the gap between information available and conservation solution, including tools to implement conservation at scale, expands. For example, today the requirements for effective marine protected areas are well understood for the conditions of the ocean a decade ago. The gap is immense when considering policy in the context of the Law of the Sea. Marine science claims to have a conservation implication but, in practice, goals are rarely directly aimed at solving conservation issues; conservation ends being a collateral product of the marine scientific endeavor. Few species within marine diversity illustrate these gaps better than pelagic birds and mammals, animals that operate over the global ocean. While we understand that these species are distributed over millions of square kilometers, and that their protection requires movable, seasonal and/or transboundary protected areas, policy and governance scenarios are not aligned to work that way. Not even at the discourse level conservation efforts properly reflect the need to evolve and adapt to incorporate our greater understanding into conservation practice. Common to commercial fisheries and pelagic predators is that they both operate at large scales. But while fisheries have been developed within a framework that has gained global political support (sustainability), the conservation of top predators is most effective at the local level, independent of the need for global action. Aligning the priority of science with those of conservation may require adaptation, but to fulfill the need is of paramount importance if the Anthropocene is not to be the era that lasted the least.

Climate change impacts and adaptation options for high trophic level marine species

Hobday A.

Variability in ocean conditions results in significant impacts to high trophic level species - seabirds, marine mammals, tuna, billfish, and sharks - and to the dependent human systems. This historical patterns provide insight into the future impact of climate change, although some marine species and socio-ecological systems have already been affected due to changes in the productivity of the ocean and hence the distribution of suitable species habitat. For example, poleward movement of habitat ranges are commonly reported and projected to occur in many regions, as are declines in productivity. These changes are exacerbating many existing conflicts between biological and human systems, adding to the societal challenge in adapting. In response to these projections, managers and policy makers are now seeking advice around possible options for reducing the impact of these changes for a range of marine species. These options can be applied to habitats, species, as well as the dependent human systems, such as by changes in management regulations for fisheries, or in managing existing stressors. Developing and evaluating a range of adaptation options now is now important, even as the evidence for impact continues to accumulate, and adaptive management responses represent a useful way forward. While adaptation options may be difficult to implement for many iconic species in the open ocean, recent adaptation projects demonstrate success at some more tractable regions, e.g. seabird and turtle colonies on islands. However, recent improvements in ocean model resolution has provided contrasting projections compared to coarser models, leading to uncertainty that has clouded our understanding. Thus, developing robust adaptation pathways that can guide future decision making will be critical to see high trophic level species continue to deliver a wide range of ecosystem services and be enjoyed by future generations.

Parallel Sessions

A - Ocean Observations and Modelling

- **A1** - The ocean carbon cycle at a time of change: data syntheses, analyses and modelling
- **A2** - Synthesis of ecological and biogeochemical variability determined from time-series Eulerian and large spatial scale transect observations
- **A3** - Modelling and data synthesis of marine planktonic ecosystems using functional types and trait-based approaches
- **A4** - End-to-end modelling for research and management

B - Lower Trophic Level Processes and Dynamics

- **B1** - The dark ocean: recent progress in understanding the functioning of the ocean's largest subsystem
- **B2** - Microbial and geochemical perspectives of global carbon cycling and climate change: from genes to ecosystems, from ancient to current
- **B3** - The pivotal role of the mesopelagic functional groups in biogeochemical cycles
- **B4** - Ocean biogeochemical dynamics under changing climate: feedbacks and impacts

C - Higher Trophic Level Processes and Dynamics

- **C1** - Beyond 'Z': what modellers need and empiricists have to offer to better incorporate higher trophic levels and humans in end-to-end models
- **C2** - Not so simple: developing robust approaches to the use of indicators for ecosystem based fisheries management [CANCELLED]
- **C3** - Integrated studies of the impact of climate change on marine ecosystems

D - Ocean Sustainability

- **D1** - Marine environmental status and biodiversity: from structure to functionality, delivering ecosystem services
- **D2** - Communities of practice for supporting long-term sustainability of the world's oceans
- **D3** - Responses of society to marine and global changes as a core mandate for IMBER: ways forward (co-sponsored by PICES)
- **D4** - Future Oceans' stewardship: roles, responsibilities and opportunities in small-scale fisheries
- **D5** - Tracking for conservation

E - IMBER Regional Programmes – Synthesis and New Research Directions

- **E1** - Changing ecosystems in Subarctic and Arctic regions
- **E2** - Detecting, projecting and managing the impacts of change in Southern Ocean ecosystems
- **E3** - Biogeochemical and ecological impacts of boundary currents in the Indian Ocean

F- Regional Studies – Responses to Drivers and Stressors

- **F1** - Climate-biogeochemistry interactions associated with open-ocean oxygen minimum zones
- **F2** - Regional responses to climatic and non-climatic drivers in a high-CO₂ ocean

Parallel Sessions

- **F3** - Impacts of anthropogenic stressors and climate change on biogeochemistry - ecosystem in continental margins and feedbacks to earth system and society: Challenges and solutions
- **F4** - Environmental changes in Eastern Boundary Upwelling Systems: drivers, mechanisms and implications for the ecosystems

G - IMBER Focus Activities

- **G1** - Contributions to IMBER Research [CANCELLED]
- **G2** - IMBER National Programme Contributions Poster Session

Session A1: The ocean carbon cycle at a time of change: data syntheses, analyses and modelling

Oral Presentations

Tuesday 24 June, 11:00-12:30 Parallel session 1
Room K2

Time	Presenter	Title
11:00-11:30	Feely, Richard	Increased Sea-Air CO ₂ Flux in the Eastern Equatorial Pacific Ocean After the 1998 PDO Regime Shift
11:30-11:50	Clement, Dominic	A C*-based extended multiple linear regression method to determine decadal changes in anthropogenic CO ₂ in the ocean
11:50-12:10	Gruber, Nicolas	Toward a global synthesis of the oceanic carbon sink since the mid 1990s
12:10-12:30	Tanhua, Toste	Transient tracer data in the GLODAPv2 data collection to estimate the decadal increase of anthropogenic CO ₂ in the global ocean

Tuesday 24 June, 14:00-15:30 Parallel session 2
Room K2

Time	Presenter	Title
14:00-14:20	Eide, Marie	Global Ocean ¹³ C-Suess effect and uptake of anthropogenic CO ₂
14:20-14:40	Landschützer, Peter	Reinvigoration of the Southern Ocean carbon sink
14:40-15:00	Bianchi, Alejandro	New estimates of CO ₂ uptake in the Weddell Sea
15:00-15:20	Sweeney, Colm	Observational indicators of change to the Southern Ocean carbon system from the Drake Passage Time Series Experiment
15:20-15:30	All	General Discussion

Session A1: The ocean carbon cycle

Tuesday 24 June, 16:00-17:30 Parallel session 3
Room K2

Time	Presenter	Title
16:00-16:20	Luchetta, Anna	Five years of observations on ocean acidification in the North Adriatic Sea. The experience of PALOMA station, Gulf of Trieste.
16:20-16:40	Gaxiola-Castro, Gilberto	Ocean carbon budget in the IMECOCAL zone of the southern California Current
16:40-17:00	Humphreys, Matthew	Surface ocean measurements of carbonate chemistry and other biogeochemical variables in the Scotia Sea, January 2013: Variability, Forcings and Consequences
17:00-17:20	Lo Monaco, Claire	Anthropogenic and Climate Impacts on the Total CO ₂ Increase Observed in the South Indian Ocean
17:20-17:30	All	General Discussion

Wednesday 25 June, 11:00-12:30 Parallel session 4
Room K2

Time	Presenter	Title
11:00-11:18	Rödenbeck, Christian	Data-based sea-air CO ₂ flux estimation - The Surface Ocean pCO ₂ Mapping intercomparison (SOCOM)
11:18-11:36	Lauvset, Siv K.	Evaluation of changes in global pH and CaCO ₃ from WOCE to CLIVAR
11:36-11:54	Liu, W. Timothy	Ocean Surface Carbon Dioxide Fugacity Observed from Space
11:54-12:12	Rios, Aida F.	Decadal acidification in the water masses of the Atlantic Ocean
12:12-12:30	Cross, Jessica	Formation and transport of corrosive water in the Pacific Arctic Region (PAR)

Session A1: The ocean carbon cycle

Wednesday 25 June, 14:00-15:30 Parallel session 5

Room K2

Time	Presenter	Title
14:00-14:20	Tilstone, Gavin	Spatial and temporal variability in satellite estimates of net community production over the Atlantic basin.
14:20-14:40	Henson, Stephanie	Variability in efficiency of organic carbon export
14:40-15:00	Heinze, Christoph	Does it make sense to include interactive sediment modules in global carbon cycle models for applications on decadal-centennial time scales?
15:00-15:20	Lo Monaco, Claire	Spatiotemporal variability of $\delta^{13}\text{C}$ -DIC in surface ocean: Observations versus Models
15:20-15:30	All	General Discussion

Wednesday 25 June, 16:00-17:30 Parallel session 6

Room K2

Time	Presenter	Title
16:00-16:18	Olsen, Are	Presenting GLODAPv2, ocean biogeochemical time trends and future plans
16:18-16:36	Pfeil, Benjamin	The Surface Ocean CO ₂ Atlas (SOCAT) community effort: outlook for versions 3 and 4
16:36-17:54	Fassbender, Andrea	Autonomous Ocean Carbon Monitoring with a Moored DIC Sensor
17:54-17:12	Tengberg, Anders	Coastal eutrophication studied in situ using multi-parameter platforms
17:12-17:30	Orr, James	Comparison of seven packages that compute ocean carbonate chemistry

Session A1: The ocean carbon cycle

Poster Presentations

Tuesday 24 June, 17:30, Poster Session 1

ID	Presenter	Title
A1.P01	Akhand, Anirban	An increasing trend in surface water fugacity of carbon dioxide in the Bay of Bengal over the last decade
A1.P02	Aksnes, Dag L	Background light attenuation - a forgotten player in ocean models?
A1.P03	Bakker, Dorothee	Summertime carbonate chemistry of northwestern European shelf seas
A1.P04	Battaglia, Gianna	Constraining Watercolumn Dissolution of Calcite and Aragonite Using Ocean Carbon Data Assimilation
A1.P05	Flecha, Susana	Monitoring carbon exchange at a time of change: observations at the GIFT (Gibraltar Fixed Time Series).
A1.P06	Gomez, Renaud	Decadal change in pH evaluated in sub-Antarctic mode water from observations collected in the southern Indian ocean
A1.P07	Haller, Michael	Application of FerryBox measurements to oxygen flux estimates in European Coastal waters
A1.P08	Hoppema, Mario	Changes in the Weddell region and anthropogenic carbon dioxide
A1.P09	Jones, Steve	Decadal trends in surface ocean pCO ₂
A1.P10	Kojima, Atsushi	Trend of ocean acidification over the global oceans
A1.P11	Kosugi, Naohiro	What has caused the rapid acidification in North Pacific subtropical mode water?
A1.P12	Luchetta, Anna	CO ₂ variables and dissolved oxygen in the central Mediterranean Sea on spatial scale (from regional to local)
A1.P13	Nakaoka, Shin-ichiro	Observation-based estimate of global pCO ₂ distribution from 1998 to 2008 using a neural network technique
A1.P14	Omar, Abdirahman	Annual and interannual variations of carbon cycling parameters in Arctic and temperate Norwegian fjords
A1.P15	Rödenbeck, Christian	What can SOCAT pCO ₂ observations and atmospheric oxygen observations tell about ocean-atmosphere CO ₂ flux variability?
A1.P16	Sabia, Roberto	A preliminary attempt to estimate surface ocean pH from satellite observations
A1.P17	Salihoglu, Baris	The link between eutrophication and acidification in the Black Sea: a modelling study
A1.P18	Schuster, Ute	Variability of the northern hemisphere air-sea CO ₂ flux over the last decade
A1.P19	Yasunaka, Sayaka	Basin-scale Distribution and Seasonal to Inter-annual Variation of Dissolved Inorganic Carbon over the North Pacific

An increasing trend in surface water fugacity of carbon dioxide in the Bay of Bengal over the last decade

Akhand A., Chanda A. and Hazra S.

The role of oceans and their significance from the perspective of global carbon cycle has been long realized. Oceans as a whole are generally considered as sinks for atmospheric carbon dioxide which has created a menace in the last century owing to its greenhouse effect. Out of the total oceanic regime, the neritic zone always draws attention as they are the most biologically active zone of the ocean. The continental shelves, especially those where large river confluences, are considered to act as CO₂ pumps with a significant potential of CO₂ uptake. On the contrary, some observations show that the shelves or coastal ocean act as net heterotrophic reservoirs as most of the river-borne particulate organic carbon is being respired here.

The Bay of Bengal (BoB) forms the eastern flank of the northern Indian Ocean, which is relatively a small basin of 2.2×10^6 km² area. Several perennial rivers end their course in this Bay which provides a steady freshwater input in the shelf area of the entire eastern coast of India.

In the present study, we have measured the fugacity of carbon dioxide (fCO₂) in the northern Bay of Bengal. Vessels were hired and pH, salinity, water surface temperature were measured on board randomly through a 50 km transect from the shoreline. Samples were taken back to laboratory to analyse the total alkalinity and nutrients like nitrate and phosphate. Using the software CO₂SYS.XLS the fCO₂ (water) was calculated.

A positive correlation was found between SST and fCO₂ (water). This relationship has been used to estimate fCO₂ (water) from the remotely sensed SST data.

Annual mean sea surface temperature (SST) of the northern Bay of Bengal during the last decade has been estimated from the remote sensing data of moderate resolution imaging spectro-radiometer (MODIS). The annual composite daytime level 3 data with a spatial resolution of 4 km has been used for this study. An increasing trend of surface water SST has been found with the rate of 0.076°C per year during the decade (2003 to 2012). A minimum fCO₂ (water) of 346 µatm was observed in the year 2007 and a maximum of 371 µatm was observed in the year 2010.

Analysing the data, an overall increasing trend of fCO₂ (water) at the rate of 1.49 µatm has been observed through the last decade.

Keywords: fCO₂, SST, BoB, RS; MODIS, Trend

Poster presentation

Background light attenuation - a forgotten player in ocean models?

Aksnes DL.

Ocean photosynthesis is constrained to the upper part of the water column (the euphotic zone). On the global scale, the thickness of this layer ranges from 1 to 200 m depth. The extension of this layer relates directly to the water column light attenuation. It is the amount of phytoplankton, other particles, and dissolved matter that determine how rapidly light is attenuated. Ecosystem and biogeochemical models commonly account for the effect of phytoplankton on light attenuation (e.g. shelf shading). The effect of the other light attenuators, however, is frequently lumped into a common background light attenuation coefficient that is assumed invariant in space and time. In nature, however, the variation in the background attenuation is severe. I show that this variation alone might account for the entire change in the vertical structure of phytoplankton and nutrients that are observed along a typical oceanic – coastal transect. This does not mean that variation in background attenuation is the only driver for vertical ecosystem structure, but it strongly suggests that this variation needs to be accounted for in ecosystem and biogeochemical modelling.

Keywords: vertical structure, ecosystem model

Poster presentation

Summertime carbonate chemistry of northwestern European shelf seas

Bakker D.C.E. and Lee G.

The relative strength of stratification and mixing is a key factor in the summertime carbonate chemistry of shelf sea waters, as shown for northwestern European shelf seas in June-July 2011. Stratification of the water column separates primary production in the surface mixed layer from subsurface respiration. Strongly stratified profiles with uptake of atmospheric carbon dioxide (CO₂) by surface waters and high subsurface dissolved inorganic carbon concentrations are found in the Celtic Sea, on the Scottish shelves and in the northern North Sea. By contrast, fully mixed profiles with little CO₂ air-sea transfer occur in the northern Irish Sea. Stratification also results in a lower saturation state of calcite and aragonite in subsurface waters than in the surface mixed layer. The lowest aragonite saturation in the shelf sea waters of 1.7 is found in subsurface northern North Sea waters. Riverine input of freshwater with a varying carbon and alkalinity content further impacts carbonate chemistry and air-sea CO₂ transfer. Off-shelf transport of the subsurface layer with its high carbon content to the adjacent deep ocean is an essential ingredient of the shelf sea carbon pump mechanism. However, off-shelf transport strongly varies along the northwestern European shelves, implying that summertime air-sea CO₂ fluxes are only a partial predictor for the strength of the shelf sea carbon pump.

Keywords: carbonate chemistry shelf seas mixing stratification

Poster presentation

Constraining water column dissolution of calcite and aragonite using ocean carbon data assimilation

Battaglia G., R. Roth, M. Steinacher and F. Joos

Calcium carbonate (CaCO_3) precipitated in the surface ocean by calcifying organisms (mostly coccolithophorids) gets re-distributed in the water column as the sinking particles dissolve at depth. Critically, this dissolution is believed to depend non-linearly on the degree of undersaturation of the ambient sea water with respect to the different CaCO_3 minerals (mostly calcite and aragonite) leaving the compensation depth. We introduced such a formulation in the Bern3D Earth-System Model of Intermediate Complexity (EMIC). The Bern3D features a 3-D frictional-geostrophic ocean model and simple OCMIP-2 type marine carbon cycle. To constrain the free parameters introduced by the redissolution parametrization, we run our EMIC in a Monte-Carlo setup and used GLODAP's potential alkalinity dataset as a constraint for the calcium carbonate cycle. Compared to the standard CaCO_3 dissolution - which uses constant exponential scaling - we find that including a omega-dependent dissolution rate does not per-se increase the model's skill in reproducing observed potential alkalinity. Nevertheless, ocean carbon data can now be interpreted in a more process-based manner. Ultimately, as pCO_2 is also a function of alkalinity, being able to simulate the vertical distribution of alkalinity similar to observations including the implementation of realistic sensitivities is very important for climate projections.

Keywords: calcium carbonate cycle, data assimilation

Poster presentation

New estimates of CO₂ uptake in the Weddell Sea

Bianchi A. and Perlender H.I.

Underway observations of sea surface temperature, salinity, carbonate systems, pCO₂, dissolved O₂, nutrients, phytoplankton taxonomy and total chlorophyll-a for three size filters (< 0.5µm, >10µm and 5µm < Chl-a <10µm), and atmosphere CO₂ partial pressures were taken in the western Weddell Sea along 10 transects during the austral summer of 2001 to 2006. XBT sections allow identifying the Weddell Front and the Slope Front. Mean values of ΔpCO₂ and Chl-a are -60µatm and 1.45mg·m⁻³. The summer areal mean CO₂ uptake in the western Weddell Sea is 7.8 mmol·m⁻²·day⁻¹. About 88% of this region acts as a CO₂ sink. Peaks in the sea-air ΔpCO₂ of -200µatm, among the highest in the global ocean, were observed. Upwelling of CO₂ rich waters driven by Ekman divergence within the Weddell Sea cyclonic gyre leads to a moderate emission in this region. In the Southern Weddell Sea, including the shelf region, the maximum CO₂ sink and high chlorophyll concentration are observed. The CO₂ capture and the Chl-a concentration are much larger than reported in the eastern Weddell. The horizontal distribution of Chl-a shows that the Weddell is not oligotrophic. Similarly, high chlorophyll values are observed in other regions too. The highest chlorophyll concentration exceeding 5mg·m⁻³ is observed near the Slope Front and on the shelf. This Chl-a concentration is remarkably higher than previously reported, suggesting significantly higher biological activity than previously thought. The capture of CO₂ in this region is presumably associated with the high abundance of large diatoms (mainly *Pseudo-nitzschia*). The diatoms abundance and the high biomass may explain the high accumulation rate of opalines and carbon observed in bottom sediments. Our results suggest that the annual uptake of CO₂ (0.02GTC·year⁻¹) is about twice of previous estimates, which may have grossly underestimated the role of the biological CO₂ pump in this region.

Keywords: CO₂ fluxes, Weddell SEA

Oral presentation

A C*-based extended multiple linear regression method to determine decadal changes in anthropogenic CO₂ in the ocean

Clement D. and Gruber N.

The repeat hydrography program provides homogenized datasets enabling different methods to calculate a decadal change in the anthropogenic CO₂ inventory based on in-situ measurements. However, all methods face the difficulty of a scarce dataset in both space and time, making the use of an appropriate interpolation technique a crucial element of any method. Here we present a new method based on the parameter C*, whose variations reflect the total change in dissolved inorganic carbon (DIC) driven by the exchange of CO₂ across the air-sea interface. Applying the extended Multiple Linear Regression method on C* on isopycnal surfaces across whole ocean basins, combined with the transient steady state assumption, we address the spatial and temporal interpolation challenges. Using synthetic data from a hindcast simulation with a global ocean biogeochemistry model (NCAR-CCSM with BEC), we tested the method for robustness and accuracy in determining ΔC_{ant} . We will present data-based results for all ocean basins, with the most recent estimate of an uptake of about 2.1 Pg C yr⁻¹ (1994-2006). These results are compared with regional and global estimates from other methods interpreting this dataset.

Keywords: anthropogenic CO₂, carbon uptake, C*, eMLR

Oral presentation

Formation and transport of corrosive water in the Pacific Arctic Region (PAR)

Cross J.N., Mathis J.T., Evans W., Pickart R.S. and Feely R.A.

In the Pacific Arctic Region (PAR), recent field observations have shown clear evidence for substantial biogeochemical preconditioning of the Pacific inflow to the central Arctic Ocean, with implications for the North Atlantic. Here, we present a synthesis of newly collected carbon measurements from several observational programs and the first autonomous carbon sensors deployed in the PAR. These data show that CO₂ accumulates seasonally from water column and sedimentary respiration over the shallow shelf of the Chukchi Sea during summer and fall. The high-CO₂ waters are transported off the shelf, with some of this export passing through Barrow Canyon. Our observations show that the Chukchi-influenced waters of Barrow Canyon are corrosive to aragonite minerals during fall. Off the shelf, these preconditioned waters feed the Beaufort Sea shelfbreak jet, where moored observations indicate predominantly corrosive conditions from May to October. Short, periodic instances of non-corrosive conditions in the boundary current from November to March are evident during the arrival of pulses of warmer waters that were resident on the Chukchi shelf during the previous summer. Overall, the corrosivity of the boundary current impacts two primary regions as it flows eastward from the Chukchi Sea: the Canada Basin and the Canadian Archipelago. Eddies, jets, and other instabilities in the boundary current are known to ventilate the Pacific layer of the Arctic Ocean halocline, and evidence of this corrosive boundary current water can be seen throughout the interior Canada Basin. The remainder of the water in the eastward-flowing boundary current is further modified by upwelling events before it eventually enters the Canadian Archipelago enroute to the North Atlantic. As a whole, this new synthesis of boundary current observations in the PAR indicates that strong biogeochemical preconditioning occurring over the broad Chukchi shelf has important implications for ocean acidification processes in the central Arctic Ocean, the Canadian Archipelago, and the North Atlantic.

Keywords: Pacific Arctic, CO₂, biogeochemistry, moored observations

Oral presentation

Global Ocean ^{13}C -Suess effect and uptake of anthropogenic CO_2

Eide M., Olsen A. and Ninnemann U.

The change in $\delta^{13}\text{C}$ of dissolved inorganic carbon has been used to determine the oceanic uptake of anthropogenic CO_2 over the entire industrial period. By applying the approach of Olsen and Ninnemann (2010) on data from 25 World Ocean Circulation Experiment cruises, the total decrease in $\delta^{13}\text{C}$ (^{13}C Suess effect) since the industrial revolution was first estimated for sections spanning all major oceans. Next, these estimates were interpolated over the global ocean using a multilinear regression technique, by first expressing the ^{13}C Suess effect as a function of temperature and CFC-11 on a per basin scale, and next applying these functions on the World Ocean Atlas and GLODAPv1.1 gridded fields. Our global 3D fields of the ^{13}C Suess effect are found to skilfully portray the change in $\delta^{13}\text{C}$ caused by the intrusion of isotopically light anthropogenic CO_2 into the oceans. The strongest ^{13}C Suess effect is observed in the warm, and well ventilated sub-tropical gyre waters in all basins, as well as in the sub-polar gyre of the North Atlantic, where a total industrial period decrease in $\delta^{13}\text{C}$ of $\sim -0.7\text{‰}$ is common. The North Atlantic is also the only region where a significant ^{13}C Suess effect is found beneath intermediate depths, with a decrease in Labrador Sea Deep Water $\delta^{13}\text{C}$ as strong as -0.5‰ . The well-ventilated mode and intermediate waters formed in the Southern Ocean have a ^{13}C Suess effect of -0.4‰ . The global mean depth-integrated anthropogenic change in $\delta^{13}\text{C}$ is estimated to -320‰ m . Our new estimate of the depth integrated change in $\delta^{13}\text{C}$ allow us to estimate the total global uptake rate of anthropogenic CO_2 , following the 'inventory approach' of Quay et al. (1992).

Olsen, A. & Ninnemann, U. 2010. Large $\delta^{13}\text{C}$ gradients in the preindustrial North Atlantic revealed. *Science*, 330, 658-659.

Quay, P., Tilbrook, B. & Wong, C. 1992. Oceanic uptake of fossil fuel CO_2 : Carbon-13 evidence. *Science*, 256, 74-79.

Keywords: Suess effect, CO_2 uptake

Oral presentation

Autonomous Ocean Carbon Monitoring with a Moored DIC Sensor

Fassbender A., Sabine C., Meinig C., and Lawrence-Slavas N.

Ocean carbon monitoring efforts have increased dramatically in the past few decades. This has largely been in response to the need for better marine carbon cycle characterization in order to accurately project the impacts of ocean acidification and climate change on marine ecosystems and to study climate feedback mechanisms. Advances in autonomous instrumentation now make it possible to study high temporal frequency (e.g. hourly) changes in marine carbon chemistry from moored platforms. This has been particularly helpful in learning more about the linkages between carbon dioxide (CO₂) and primary production due to the importance of episodic events in biological carbon uptake and export. NOAA-PMEL currently maintains ~40 CO₂ buoys that are deployed at locations all around the world, and many of these buoys are now outfitted with pH sensors, making it possible to fully constrain the carbonate system and conduct ocean carbon cycle studies. Unfortunately, due to the strong covariance between pH and pCO₂, this is the least desirable pair of carbonate system parameters (dissolved inorganic carbon, total alkalinity, pH, and pCO₂) to measure in order to evaluate marine carbonate chemistry via bulk mass-balance approaches. As part of my doctoral research, I have developed a robust dissolved inorganic carbon (DIC) sensor prototype that will more accurately characterize seawater carbon chemistry when paired with pCO₂ or pH measurements on moorings. This sensor bubbles initially-CO₂-free air through ~1mL of acidified seawater, and at equilibrium, the quantity of CO₂ evolved from the sample is used with the ideal gas law to determine seawater DIC concentration. This method is similar to techniques that have been used reliably on shipboard underway DIC systems, but has not previously been adapted for long-term time series observations on a mooring. The prototype DIC sensor is being tested at the Seattle Aquarium, a coastal estuary, and off the south shore of Oahu, HI, a more stable oceanic environment. Results from these field deployments will be shared.

Keywords: DIC, autonomous sensors, marine carbon cycle

Oral presentation

Increased Sea-Air CO₂ Flux in the Eastern Equatorial Pacific Ocean After the 1998 PDO Regime Shift

Feely R.A., Cosca C.E., Sutton A., Wanninkhof R., McPhaden M. and Mathis J.T.

In order to obtain a fundamental understanding of the physical controls of the decadal changes of the sea-air CO₂ flux from the equatorial Pacific, we developed seasonal and interannual relationships between the fugacity of CO₂ (fCO₂) and sea surface temperature (SST) from shipboard and mooring observations from the SOCAT database. These data were applied to high-resolution temperature fields obtained from satellite data to establish large-scale estimates of CO₂ fluxes. The data were gathered on board research ships from 1981 thru 2011 for the region between 6°N-10°S, 85°W-165°E. Observations made during the warm boreal winter-spring season and during the cooler boreal summer-fall season of each year enabled us to examine the interannual and seasonal variability of the fCO_{2sw}-SST relationships. The fitted data yielded an inverse correlation between SST and fCO_{2sw}, with both interannual and seasonal differences in slope. The results indicated a significant increase (25-30%) in the out-gassing flux of CO₂ after the recent 1998 PDO mode shift, which is dominated by more frequent La Niñas and Central Pacific El Niños. Most of this increase is due to increase in wind speeds in the eastern Pacific after the spring of 1998 that led to a shift in the fCO_{2sw}-SST relationship during the El Niño periods. This long-term change in the tropical Pacific is the largest decadal change in sea-air CO₂ Flux observed in both observations and models for the entire Pacific Ocean.

Keywords: Sea-Air CO₂ Flux, El Niños

Oral presentation

Monitoring carbon exchange at a time of change: observations at the GIFT (Gibraltar Fixed Time Series).

Flecha S., I.E. Huertas I.E., Prieto L., Hilmi K., Zizah S and Ruiz J.

The Strait of Gibraltar, as the only connection of the Mediterranean Sea with the rest of the world's oceans, represents the most suitable spot to track carbon exchange between basins. Water circulation in the Strait is characterized by an eastward surface inflow of Atlantic waters (AI) that is compensated by a deep outflow of Mediterranean waters (MOW), which abandons the basin towards the North Atlantic through the Gulf of Cadiz. This pattern of water exchange exhibits large fluctuations at different time scales, from seasonal and subinertial, both modulated by the change of atmospheric pressure in the Mediterranean basin, to tidal variability. The MOW and AI are the mixture of different water bodies that appear either intermittently or mixed in changing proportions throughout the year, which creates considerable spatial and temporal variations in the position and intensity of both water flows. This exchange of water masses with distinct thermohaline properties and carrying compounds at a different concentration influences the biogeochemical inventories of the Mediterranean and Atlantic basins. In particular, atmospheric CO₂ capture in the region and carbon transport through the channel are complex processes that are being monitored since 2005 at the Gibraltar Fixed Time Series (GIFT). In addition, a mooring line was deployed at the GIFT in 2011 to examine the temporal variability of the carbon content in the Mediterranean water. The mooring line contains submersible autonomous sensors (SAMI-CO₂ and SAMI-pH) to continuously record in situ pCO₂ and pH. Data gathered at the GIFT is allowing us to identify relevant carbon cycle processes, such as ocean acidification, at a basin scale. Here we present a summary of the main results obtained in the area as a consequence of this monitoring program along with new records at a high temporal resolution. Data analysis has been performed taking into account the variability in the proportion of the different water masses appearing in the Strait of Gibraltar.

Keywords: Mediterranean, ocean acidification, CO₂, Gibraltar Strait

Poster presentation

Ocean carbon budget in the IMECOCAL zone of the southern California Current

Gaxiola-Castro G., Cepeda-Morales J., De la Cruz-Orozco M.E., LavaniegosB.E., Hernández Ayón J.M-, Durazo R., Castro R.

The IMECOCAL zone located in the southern section of the California Current off Baja California represents one of the regions where ocean carbon budgets are important as consequence of coastal upwelling processes; high spatial and seasonal water masses variability with interactions between temperate and subtropical conditions, and mesoscale processes contributing to ocean dynamical processes. In this variety of changing environment it is necessary to understand the carbon budgets (balances of carbon exchange between the main reservoirs and the epipelagic ecosystem) in the upper water-column, where the main exchanges are current. The average CO₂ ocean-air flux calculated using seasonal underway pCO₂ data from the IMECOCAL surveys is 0.80 mmol m⁻² d⁻¹ (~0.29 mol CO₂ m⁻² y⁻¹) diminishing offshore, with a strong seasonal variability mainly derived from coastal upwelling and by seasonal and yearly changes in the California Current main flow. On the average, the region is a weak source of CO₂ to the atmosphere, with high fluxes only during upwelling seasons (spring and summer) and on coastal areas. The reservoir of dissolved inorganic carbon (DIC) in the epipelagic zone (~200 m depth) is approximately 2500 gC m⁻², with an averaged transference rate to organic carbon of 0.67 gC m⁻² d⁻¹ by phytoplankton photosynthesis. The general average of particulate organic carbon (POC) calculated from the phytoplankton chlorophyll-a is 1.64 gC m⁻², with a ten-fold difference between onshore and offshore areas. Zooplankton carbon for the region is 0.98 gC m⁻², obtained using biomass volume (bongo nets) and empirical relationships for total zooplankton weight. From these estimations, zooplankton organisms incorporated approximately 60% of the POC. The organic carbon flux below the permanent thermocline (> 200 m deep) is ~0.01 gC m⁻² d⁻¹, representing ~1.5% of the phytoplankton photosynthetic organic carbon. The higher carbon phytoplankton-zooplankton transferences rates and the lower organic carbon vertical flux below the epipelagic zone, appears to show high carbon conversion efficiency at lower trophic level in this temperate-subtropical region of the Pacific Ocean.

Keywords: Ocean carbon budget, California Current

Oral presentation

Decadal change in pH evaluated in Subantarctic mode water from observations collected in the southern Indian ocean

Gomez R., Lo Monaco C., Metzl N., Lourantou A. and Steten E.

The Southern Ocean is an important sink for atmospheric CO₂ and a region of Subantarctic Mode Water (SAMW) formation. This results in a large accumulation of anthropogenic carbon (C_{ant}) in the ocean between 30°S and 50°S, which leads to a decrease in seawater pH. This acidification process could impact the biological pump of CO₂ and thus global climate. In this context, we used total alkalinity (TA) and dissolved inorganic carbon (DIC) measurements collected in the Southern Indian Ocean from 1985 to 2013 to estimate the acidification rate of SAMW. Over this period, pH decreased by 0.014/decade. This rate is close to the one evaluated in subantarctic surface waters in the same region (0.013/decade). In addition we found that the acidification rate was not solely controlled by the accumulation of C_{ant}. In this region, natural variability or climate-induced changes in the carbonate chemistry tend to reduce the rate of acidification.

Keywords: acidification, SubAntarctic Mode Waters, Indian Ocean

Poster presentation

Toward a global synthesis of the oceanic carbon sink since the mid 1990s

Gruber N., Clement D., Landschützer P., Tanhua T., Ishii M., Mathis J.T., Lenton A., Bakker D., Wanninkhof R., and Olsen A.

While the ocean has continued, over the last decades, to take up a substantial amount of the CO₂ emitted into the atmosphere by human activities, we do not have yet a global-scale data-based quantification of this uptake. To arrive at such estimates, substantial efforts have been undertaken in the past five years by the international community with guidance by the IMBER/SOLAS carbon working groups and the IOCCP to assemble, harmonize, and interpret global ocean surface and interior carbon data sets, such as SOCAT (www.socat.info) and GLODAP2. Interpretation of these data sets is still on-going, but first products emerging are (i) an estimate of the oceanic accumulation of anthropogenic CO₂ between the 1990s and the mid-2000s (Gruber et al., in prep.), and (ii) monthly resolved global air-sea CO₂ fluxes for this entire period (e.g., Landschützer et al., in prep.). Here, we aim to synthesize these two products in order to assess the consistency in time and space between the time-integrated air-sea CO₂ fluxes and the changes in ocean interior storage. The preliminary results suggest a global increase in the inventory of about 25 Pg C between 1994 and 2006, while the cumulative air-sea CO₂ flux over this period amounts to about 19 Pg C. Assuming a cumulative outgassing flux of ~5 Pg of “natural” carbon stemming from the carbon input by rivers, the global ocean interior and surface perspective are consistent with each other, suggesting a mean oceanic uptake flux of about 2.0 Pg C yr⁻¹ over this period. This flux is at the lower end of most other estimates (e.g., atmospheric data and ocean inversions). If correct, the ocean sink would have been smaller than expected from the increase in atmospheric CO₂.

Keywords: Anthropogenic CO₂, ocean carbon sink,

Oral presentation

Application of FerryBox measurements to oxygen flux estimates in European coastal waters

Haller M., Peterssen W. and Callies U.

The monitoring of marine environments in coastal seas is still a challenge when continuous and reliable observations are needed, especially in context of climate change and increased anthropogenic impact on coastal waters. Ships of opportunity (SoO) are a platform for marine measurements, undertaken by FerryBox measurement systems. They are cost-effective and provide dependable long-term in-situ measurements of near-surface parameters. For many years, several FerryBox routes along European coastal waters have been established. One of these routes has been selected for biogeochemical analyses.

In context of climate change, the evaluation of quantitative values regarding the cycles of oxygen in the oceans is an important task as dissolved oxygen plays a major role in net primary production and ocean acidification. The processes of gas exchange, that is a part of the carbon and oxygen cycles, are strongly influenced by water temperature, salinity and wind speed. Empirical functions are used for parameterisation of the gas transfer velocity and have been under discussion for years.

Onboard the FerryBox systems, optodes provide continuous measurements of dissolved oxygen concentrations along transects and, thus, are a valuable instrument for monitoring the oxygen levels in the ocean surface layer. Together with temperature and salinity observations as well as wind field information derived from ECMW reanalyses and from DWD forecasts, the air-sea exchange of oxygen has been calculated for parts of the southern North Sea and the German Bight. Details of the analyses procedure as well as results will be presented.

Keywords: oxygen fluxes, ferrybox, pCO₂, acidification

Poster presentation

Does it make sense to include interactive sediment modules in global carbon cycle models for applications on decadal-centennial time scales?

Heinze C.

Few global three-dimensional biogeochemical general circulation models include a sediment or early diagenesis module. These modules provide a dynamical coupling between the water column biogeochemistry and the processes in the bioturbated sediment zone. On decadal to centennial time scales it is often taken as granted, that the sediment dynamics of calcium carbonate, biogenic silica, and organic carbon do not contribute significantly to changes in global carbon budgets. Nevertheless, the inclusion of sediment biogeochemistry can be rewarding. First of all, the simulation of the sediment serves as a constraint for the adequate simulation of particle fluxes and export production in baseline simulations, especially when the sediment coverage across gradients in topography is considered. For example, parameterisations for the dissolution kinetics and solubility of marine calcium carbonates can be calibrated through comparisons between modelled and observed sediment distributions. Further, it can be checked whether the basic patterns of export production in the models are well reproduced in long model spin-ups, as export production is reflected both in solid sediment tracers as well as pore water tracers such as delta-C-13 of dissolved inorganic carbon. In addition, global ocean carbon cycle models which include the matter throughput from continental input (river loads, aeolian inputs) to sediment accumulation have shown a higher sensitivity to changes in external and internal forcings as models which only circulate matter within the ocean water column reservoir. Examples with the HAMOCC biogeochemical ocean general circulation model are given on how baseline integrations for carbon budget simulations can be constrained through sediment distributions and how variations in modelled atmospheric CO₂ concentrations depend on the inclusion of sediment dynamics.

Keywords: biogeochemistry, modelling, sediment

Oral presentation

Variability in efficiency of organic carbon export

Henson S., Yool A. and Sanders R.

The export efficiency (e-ratio) is the ratio of carbon exported from the mixed layer to primary production (PP). The e-ratio determines the flux of organic carbon entering the mesopelagic and plays a role in setting the vertical gradient of DIC-. Thus, there is considerable interest in extrapolating from the limited in situ estimates of e-ratio to the global scale using remotely-sensed parameters such as sea surface temperature. In addition, as in situ estimates of e-ratio are necessarily instantaneous, there is a need to extrapolate from these to an annual estimate of export flux. Here we examine global patterns in both spatial and seasonal variability in e-ratio and subsequent effect on export estimates using a high resolution global biogeochemical model as a source of idealised synthetic data. We find that both temperature and the fraction of slow sinking particles are factors in determining the e-ratio, suggesting that current empirical algorithms for e-ratio are overly simple. The temporal lag between PP and export is also quantified and is found to be greatest in regions of strong seasonal variability in PP, where seasonal decoupling can result in large temporal variability in e-ratio. As such, extrapolating from instantaneous measurements of e-ratio to annual means is strongly affected by seasonal variability, and we find that export can be erroneously estimated by up to $\pm 60\%$. This model study suggests that seasonal variability in e-ratio should be considered in the design and interpretation of in situ export studies.

Keywords: carbon export, variability, model

Oral presentation

Changes in the Weddell region and anthropogenic carbon dioxide

Hoppema M., van Heuven S., Jones E.M., Campos C., and Huhn O.

We show data from repeated sections along the Prime Meridian and across the Weddell Sea for determining the trends in Total CO₂ (TCO₂), dissolved oxygen and nutrients in different water masses including the Antarctic Surface Water, Weddell Sea Deep Water (WSDW) and Weddell Sea Bottom Water (WSBW). Assuming linear trends, along the Prime Meridian we found a clear positive trend during 1973 to 2010 for TCO₂ in the surface water and WSBW. The TCO₂ increase in the surface water is about 4 times larger than in the bottom water, which makes sense as the surface water component of the bottom water is much older than the water from the surface layer. Accompanying this increase is a remarkable decrease of oxygen and an increase of silicate and nitrate in the WSBW, with no significant changes in the surface layer. Apparently the Weddell Gyre is in a non-steady state with regard to these variables, confirming decadal changes in hydrographic properties. We must assume that part of the TCO₂ trend in the WSBW be caused by natural variation due to the non-steady state. However, the surface layer increase should be largely anthropogenic. In contrast, in the central Weddell Sea to the west, TCO₂ showed a slight but not statistically significant increase in the WSBW in the period 1992-2011. Obviously, this bottom water derives from a different source as that on the Prime Meridian, being either older or less ventilated. Near the tip of the Antarctic Peninsula, where a plume of recent bottom water can be observed, a very high rate of increase of TCO₂ over time was observed at the lowest temperatures. This points to nearly full equilibration with the (anthropogenic) CO₂ of the atmosphere in an ice-covered region. Ice cover does not seem to be a major impediment for C_{ant} uptake in this prominent deep water formation region. We assess the consequences of this important observation for the carbon transport in this region.

Keywords: Weddell Sea; anthropogenic carbon; oxygen; nutrients

Poster presentation

Surface ocean measurements of carbonate chemistry and other biogeochemical variables in the Scotia Sea, January 2013: Variability, Forcings and Consequences

Humphreys M.P., Achterberg E., and Tyrrell T.

During austral summer at the start of 2013 a range of biogeochemical parameters were measured at high spatial resolution (c. 1 discrete sample each 30 km) across the surface layer of the Scotia Sea, as part of the UK Ocean Acidification research programme. The data include a full characterisation of the carbonate chemistry system and the stable isotopic composition of dissolved inorganic carbon; C-14 primary productivity and calcification rate measurements; chlorophyll; macronutrients; and community structure from light microscopy and a continuous plankton recorder. Very low partial pressures of carbon dioxide were observed, in particular during crossings of the South Georgia bloom. These are a result of biological uptake of dissolved inorganic carbon during photosynthesis, and could drive significant uptake of atmospheric carbon dioxide. Here we present an analysis of the biogeochemical factors controlling these and other changes in carbonate chemistry, their impact on the uptake of carbon dioxide from the atmosphere into the surface ocean, and the role of carbonate chemistry parameters in influencing community structure and species distributions. In this region of strong natural gradients in carbonate chemistry, we also attempt to deconvolve anthropogenic changes to the system. Regression and neural network techniques have been applied to various components of the surface carbonate chemistry system in order to enable their prediction from remotely-sensed parameters such as sea surface temperature and chlorophyll concentration, and so estimate the air-sea flux of carbon dioxide over the whole Scotia Sea at this time.

Keywords: carbon air-sea acidification biogeochemistry response parameterisation

Oral presentation

Decadal trends in surface ocean pCO₂

Jones S.D., Le Quéré C., Rödenbeck C. and Manning A.C.

We use the newly released SOCAT v2 data set to assess the decadal trends in surface ocean pCO₂ during the 1990s and 2000s. Such long term trends are inherently valuable in understanding changes in the global carbon budgets as published by the Global Carbon Project. Additionally, a significant change in the trend of atmospheric CO₂ concentrations occurred around the year 2000 which does not reflect the continued increase in anthropogenic CO₂ emissions. This study assesses the potential role of the ocean carbon sink in the observed change in atmospheric CO₂ trends.

Keywords: pCO₂ trends variability

Poster presentation

Trend of ocean acidification over the global oceans

Kojima A., Iida Y., Takatani Y., Nakano T., Sasano D., Kosugi N., Ishii M., Midorikawa T.

The pH of ocean surface water has decreased by 0.1 since the beginning of the industrial era as a result of the invasion of the excess CO₂ into the ocean due to fossil fuel combustion and land-use changes (IPCC, 2013). This pH decrease, corresponding to the 26% increase in hydrogen ion concentration in surface seawater and is referred to as the ocean acidification, is a matter of great concern because it potentially has large negative impacts on marine organisms and ecosystems, thereby threatening societies which depend heavily on marine resources and services. To document the trend of acidification in regional as well as the global scale is critical in projecting the impacts.

In this work, we report a trend of decrease in pH and Ω_{arg} , the saturation index of aragonite, over the global oceans from 1990 through 2011 on the basis of the reconstructed monthly data sets of global CO₂ partial pressure (pCO_{2s}) and total alkalinity (TA) in surface seawater. We have developed an empirical method to estimate monthly distributions of pCO_{2s} over the global oceans with 1x1 (longitude x latitude) using the relationships between observed pCO_{2s} and other parameters including sea surface temperature (SST), salinity (SSS) and Chlorophyll-a (Iida et al, in preparation). Long-term trend of increase in pCO_{2s} has been determined for each of ocean basin and/or zonal domains by the multiple regression coefficients of pCO_{2s} and time, SST, SSS based on the SOCAT (Surface Ocean CO₂ Atlas) data base. Japan Meteorological Agency (JMA) already provides this pCO_{2s} data for public and makes a report of global ocean CO₂ exchanges every year. We also proposed new empirical equations to reconstruct TA in surface waters over the Pacific Ocean (Takatani et al. in preparation). They were derived from the PACIFICA (PACIFIC ocean Interior CARbon) database and expressed as a function of SSS and sea surface dynamic height. For other basins, distribution of TA in surface water was reconstructed from the empirical equations proposed by Lee et al. (2006)

In most regions of the ocean, pH and Ω_{arg} are showing the trend of decrease over the period from 1990 to 2011. The global average is -0.017 ± 0.005 (after value mean standard deviation, the same hereafter.) per decade for pH and -0.081 ± 0.031 per decade for Ω_{arg} . The rate of pH decrease is slightly higher in the Indian Ocean (-0.019 ± 0.001 per decade) and Southern Ocean (south of 50S, -0.019 ± 0.005 per decade) than in the Pacific (-0.016 ± 0.005 per decade) and Atlantic Ocean (-0.016 ± 0.004 per decade). The highest rate of decrease was determined in the North Pacific subtropical region because of the high pCO_{2s}, low pH and low Ω_{arg} observed in the late 2000's.

Keywords: ocean acidification, global pH mapping, SOCAT

Poster presentation

What has caused the rapid acidification in North Pacific subtropical mode water?

Kosugi N., Sasano D., Ishii M., Kojima A., Iida Y., Nakano T. and Midorikawa T.

The emission of huge amount of CO₂ by the fossil fuel combustion and land-use changes is causing a rapid increase of CO₂ in the atmosphere and in the ocean, and thereby considered to be acidifying the seawater over the global oceans. The ocean acidification is a threat to the abyssal and benthic ecosystems as well as those in the upper layers. However, the acidification in the interior of the ocean has been less investigated than in the surface layers.

Japan Meteorological Agency has been repeating the hydrographic/hydrochemical measurements along 137 degrees east in the western North Pacific to the south of Japan for past 50 years. As a part of these measurements, pH has been measured seasonally in the upper 2000 m water columns with the spectrophotometric technique since 2003. The data of pH and related ocean physical/biogeochemical parameters such as dissolved oxygen (DO) and dissolved inorganic carbon (DIC) allows us to analyze the trend of the acidification and its controlling chemical and physical processes.

The accumulation of the anthropogenic CO₂ and the acidification in the western North Pacific has been observed at every 5 degrees from 5 to 30 degrees north. It has been detected significantly at the depth of 600 m at 30 degrees north in the subtropical gyre. Meanwhile, temporal and spatial variation of acidification was much larger in the sub-surface layers than in the surface. The rate of acidification was the highest in the North Pacific Subtropical Mode Water (NPSTMW; located around 300 m depth at potential density = 1025.2 kg/m³). The rate of pH decrease in NPSTMW was up to 0.005 per year. This is about twice as fast as that in the surface. The rapid acidification in NPSTMW is attributable to the combined effect of the anthropogenic CO₂ increase and the biological degradation of organic matters calculated from the variation of apparent oxygen utilization (AOU) and Redfield ratio (DIC: DO = -117/170). These two factors have comparable impacts on the rate of acidification in NPSTMW.

The thickness of NPSTMW, i.e., the thickness of layer with the potential density between 1025.0 kg/m³ and 1025.4 kg/m³, varied dynamically at 137 degrees east during the past decade. AOU and pH in NPSTMW varied largely in response to the thickness. When NPSTMW was thick (~300 m), AOU tended to be low (~16 μmol kg⁻¹) and pH tended to be high (~8.00). In contrast, when NPSTMW was thin (~100 m), AOU tended to be high (~50 μmol kg⁻¹) and pH tended to be low (~7.94). The low AOU indicates that the mode water was relatively new and was in contact with the atmosphere until recently. These results of observation suggest that the acidification in NPSTMW has been affected considerably by the processes of NPSTMW formations and subsequent advection and degradation which are connected to the air-sea interaction and the climate. If the climate change will weaken winter convection in the NPSTMW formation region, it will provoke another type of acidification.

Keywords: Acidification, carbon cycle, mode water

Poster presentation

Reinvigoration of the Southern Ocean carbon sink

Landschützer P., Gruber N. and Bakker D.C.E.

Several studies reported a recent saturation of the Southern Ocean carbon sink, primarily as a result of the southward shift and intensification of the westerly wind belt associated with a trend toward a high index polarity of the Southern Annular Mode (SAM) over the last 50 years. However, these estimates only apply to the period up to the mid 2000-s, and therefore do not include the potential ramifications of the most recent leveling of the trend in the SAM. Here we fill this gap and investigate trends in the global air-sea CO₂ fluxes for the time period 1992 through 2011 with a particular focus on the Southern Ocean. Our analysis is based on the sea surface pCO₂ observations from the Surface Ocean CO₂ Atlas version 2 database, which we interpolated in time (monthly) and space (1° latitude x 1° longitude), using the 2-step neural network (SOM-FFN) approach developed by Landschützer et al. (2013). Relative to prior versions of our algorithm, we did not use chlorophyll as a predictor variable, permitting us to extend the time period back to 1992. The air-sea CO₂ fluxes are then computed using high resolution wind speeds and a standard bulk formulation of the air-sea gas transfer. Our results indicate a moderate level of year-to-year variability in the air-sea CO₂ fluxes, primarily driven by the Equatorial Pacific responding to El Niño Southern Oscillation (ENSO) variations. In contrast, the trend in the global ocean carbon sink is strongly determined by the Southern Ocean. Within the considered time period, the Southern Ocean carbon sink first shows a strong reduction from -0.50 ± 0.10 PgC yr⁻¹ in 1992 toward nearly balanced conditions in 2001, but then the sink increased again to a total carbon uptake of -0.64 ± 0.14 PgC yr⁻¹ in 2011. Thus, while our estimates support the notion that the Southern Ocean carbon sink saturated in the late 20th century, the recent data suggest a strong reinvigoration. This increasing sink is potentially linked to the recent reduction of the SAM index.

Keywords: carbon, Southern Ocean

Oral presentation

Evaluation of changes in global pH and CaCO₃ from WOCE to CLIVAR

Lauvset S.K., Olsen A., Key R.M., Lin X., Tanhua T., Hoppema M., Jutterström S., Steinfeldt R., Jeansson E., van Heuven S., Ishii M., Suzuki T., Velo A., Kozyr A., Pfeil B. and Schi C.

We know that over the past few decades the ocean pH has been decreasing, mostly due to perturbations in the atmospheric CO₂ concentration. The recently released GLODAPv2 data product is dominated by data from the WOCE and CLIVAR repeat section campaigns, and we expect there to be a difference between these two eras in pH and CaCO₃. There is, however, also large variability in the system which may mask the temporal trend. The global gridded version of the GLODAPv2 data (1°x1°, 33 depth layers) has been used to evaluate differences in pH and CaCO₃ between the WOCE and CLIVAR eras, which were gridded separately. Whenever possible we have compared the difference between the two atlases with time trends derived from comparing direct repeats of the same transect, such that we can make a first estimate of how much of the difference is due to temporal trends and how much is due to the internal variability. This method also allows us to eliminate some sources of error.

Keywords: pH, trends, variability, GLODAPv2

Oral presentation

Ocean Surface Carbon Dioxide Fugacity Observed from Space

Liu W.T. and Xie X.

The ocean as the source and sink of carbon dioxide is important to global warming, ocean biogeochemistry, and ecology, but its quantitative variation is insufficiently known. The exchange depends on the difference in fugacity (partial pressure) of carbon dioxide between sea and air, and a transfer velocity. The transfer velocity has traditionally been parameterized in terms of wind speed, which has been measured by a number of spacebased sensors. The fugacity in air is believed to change much less than fugacity in sea. Fugacity in sea is measured largely on ships; they are not sufficient to characterize spatial and temporal variability. Attempts have been made in the past to relate the fugacity in sea to parameters (drivers) that could be measured from space. These relations are found to be valid only in limited regions and in specific seasons. We have developed a statistical model to estimate the fugacity over global ocean for all seasons from NASA space measurements using the state-of-art statistical techniques. The input data are sea surface temperature, productivity, and salinity over global oceans. We are examining the role of these drivers in different location and seasons. The dependence of the fugacity on sea surface temperature in the tropics is replaced by dependence on productivity at higher latitudes. The change of fugacity is highly correlated to salinity around at regions affected by river discharges. The variation of ocean fugacity as a signature of ocean circulation and biogeochemistry will be presented.

Keywords: carbon-dioxide, global-warming, biogeochemistry, satellite-sensors

Oral presentation

Anthropogenic and climate impacts on the total CO₂ increase observed in the Southern Indian Ocean

Lo Monaco C., Metzl N., Lenton A., Racapé V., Brunet C., Gomez R. and Pierre C.

The Southern Ocean has been identified as a key region for the uptake of anthropogenic CO₂ through the formation of Subantarctic Mode Waters (SAMW), but its response to climate change and variability remains uncertain. This question can now be addressed directly from observations, thanks to the availability of consistent historical and recent measurements (GLODAP and CARINA synthesis). We used observations collected between 1985 and 2010 to evaluate the change in total CO₂ (TCO₂), anthropogenic CO₂ (C_{ant}) and the oceanic Suess effect in the Southern Indian Ocean, a region where SAMW is formed. The accumulation of C_{ant} in SAMW, derived from three different methods, was around 8 μmol/kg/decade, which is close to the theoretical value expected from the increase in atmospheric CO₂. The invasion of C_{ant} in the ocean explains most of the observed increase in TCO₂ concentrations and decrease in carbon 13, but not all. This suggests an increase in the 'natural' TCO₂, possibly related to the strengthening of the Southern Annular Mode over the last decades.

Keywords: Anthropogenic CO₂ natural variability, Indian Ocean

Oral presentation

Five years of observations on ocean acidification in the North Adriatic Sea. The experience of PALOMA station, Gulf of Trieste.

Cantoni C., Sparnocchia S., Luchetta A., Celio M., Cozzi S., Finotto S., Bastianini M. and Raicich F. 1

The Gulf of Trieste is a shallow bay (deep less than 25 m) lying in the northernmost part of the Adriatic Sea (Mediterranean Basin), where cold north-easterly winds often blows during winter producing cold dense water masses that are expected to be enriched in CO₂. Meteorological conditions exhibit a pronounced seasonal cycle, causing wide variations of the physical properties in the water column through the year. In January 2008 a monitoring activity started by the elastic beacon PALOMA, located in the centre of the gulf. Meteorological and marine (physical and biogeochemical) parameters were collected, aimed at studying the inorganic carbon biogeochemistry and ocean acidification process in this highly variable coastal area. Since August 2012, the time series of physical and biogeochemical parameters (T, S, nutrients, Dissolved oxygen, pHT, AT, DOC) has been improved with continuous measurements of seawater pCO₂, temperature and salinity at 3 m below the surface. In 2010 PALOMA station has been included in the North Adriatic LTER site and is often visited during basin scale surveys. Here we present the main results of these five years activity highlighting the most relevant scientific results and underpinning the potential vulnerability of this area to the acidification process.

Keywords: Ocean acidification, Times series, North Adriatic

Oral presentation

CO₂ variables in the central Mediterranean Sea on regional and local scale

Luchetta A., Sparnocchia S., Cantoni C., Kovacevic V. and Cozzi S.

Despite the general sparseness of water column carbon measurements, the Mediterranean Sea has been identified as an important anthropogenic carbon storage, where the column inventory is much higher than in the Atlantic or Pacific Oceans. The central Mediterranean Sea (Ionian and Adriatic basins) is even less sampled, although water masses locally formed and circulating are able to affect the deep overturning cell of the Eastern Mediterranean.

We refer in particular to the Adriatic sea where significant physical and biogeochemical processes (as dense water formation, river inputs, intense air sea exchanges, phytoplankton blooms, with high primary production, and remineralisation) take place thus affecting air-sea CO₂ fluxes and the related seawater carbon chemistry.

The spatial and seasonal variability of carbonate system properties (pHT, AT, DIC, fCO₂, pCO₂, carbonate saturation states) and other chemical properties (dissolved oxygen, nutrients) were determined in the first mesoscale surveys conducted in spring and autumn 2008, under the SESAME project. Observations point out latitudinal gradients of all parameters, depending on the main drivers. For instance AT surface values were the highest (> 2640 µm/Kgsw) in the Adriatic basin, in particular on the N. Adriatic shelf, due to the effect of many rivers outputs draining carbonatic basins. Data are compared with others collected within following projects (EUROFLEET and PERSEUS).

The distribution of CO₂ variables in the different water masses, characteristic of the region, is highlighted, and air-sea CO₂ fluxes in the Adriatic basin have been estimated in order to assess its role as sink or source. The Adriatic results to work as a CO₂ sink in both seasons, depending on synergy among drivers, with latitudinal differences: the North Adriatic being a strong/moderate sink, and Southern Adriatic being a weak sink.

Gained information can be integrated, on local scale (North Adriatic), with information on the temporal variability of carbonate system properties, and on the main drivers, as inferred from analysis of the time series of physical, chemical and biological parameters, acquired in the Gulf of Trieste (North Adriatic) in the last six years.

In summary the most significant results concerning the Ionian and Adriatic basins are presented. They can be further discussed as a possible contribution to studies about the interactions among multiple stressors (warming, OA and hypoxia) already affecting the area on very local scale (N. Adriatic sub basin).

Keywords: Ocean Acidification, CO₂ fluxes,

Poster presentation

Observation-based estimate of global pCO₂ distribution from 1998 to 2008 using a neural network technique

Nojiri Y., Yausunaka S., Mukai H., Telszewski M. Presented by Nakaoka, S.-I.

This study produces maps of the partial pressure of oceanic CO₂ (pCO₂) over the global ocean from 1998 to 2008. The pCO₂ values are estimated by using a self-organizing map neural network technique to explain the non-linear relationships between observed pCO₂ data and four oceanic parameters: sea surface temperature (SST), sea surface salinity (SSS), mixed layer depth (MLD), and chlorophyll-a concentration (CHL), with secular increasing pCO₂ trend. The observed pCO₂ data was obtained from Surface Ocean CO₂ Atlas (SOCAT) database version 2. The dataset of SST, SSS MLD were obtained from the GLORYS reanalysis data of the Mercator-Ocean and the Satellite CHL dataset was from MODIS-Aqua and SeaWiFS Level 3 standard product. The result clearly shows the typical pCO₂ responses to the El Nino/La Nina events, especially in the equatorial Pacific. Annual CO₂ uptake is apparent in subpolar region of the North Atlantic (north of 50°N), mid-latitude western region of the North Pacific (30°-40°N), and the Southern Ocean (south of 40°S) while annual source is seen in the equatorial Pacific, Indian Ocean (north of 20°S) and the subpolar region of the North Pacific. The total amount of annual CO₂ exchange varies from -1.7 PgC/yr to -0.9 PgC/yr.

Keywords: pCO₂, global ocean, air-sea CO₂ flux

Poster presentation

Presenting GLODAPv2, ocean biogeochemical time trends and future plans

Olsen A., Key R.M., Lauvset S.K., Lin X., Tanhua T., van Heuven S., Hoppema M., Jutterström S., Steinfeldt R., Jeansson E., Ishii M., Suzuki T., Velo A., Kozyr A., Pfeil B. and Schirnick C.

We present the global interior ocean carbon synthesis effort, Global Ocean Data Analysis Product version 2, provide examples of biogeochemical time trend signals that can be extracted from this new data product and present our plans for future interior ocean carbon synthesis activities.

GLODAPv2 assembles data from some 800 cruises where measurements of inorganic carbon and/or other carbon relevant parameters have been made. It has been constructed by merging the three existing carbon data synthesis products GLODAP, CARINA, PACIFICA, and adding data from around 100 new cruises from all major ocean areas. The data included in GLODAPv2 has been subjected to primary QC and has been bias corrected following comparison of all the deep ocean data collected at the various cruises using a crossover and inversion routine.

The data product GLODAPv2 includes the original (unadjusted) data files, the integrated bias-corrected data product, and also mapped climatologies of the variables total dissolved inorganic carbon and total alkalinity.

The biogeochemical time trend signals were extracted by using crossover and inversion routines at a series of specific depth ranges in ocean regions of size 20 x 20 degrees of latitude and longitude. When used in the deep ocean, where biogeochemistry is expected to be steady over the time period covered, this method is used to determine bias corrections. When used in the upper ocean, on the other hand, it will reveal the time trends, with the advantage of minimising the effect of spatial differences in sampling coverage from one year to another. Here we will emphasise the ocean regions where significant time trends in ocean biogeochemistry are identified.

Our plans for a sustained GLODAP effort within the framework of the International Ocean Carbon Coordination Project will also be presented.

Keywords: Ocean carbon synthesis, biogeochemical trends.

Oral presentation

Annual and interannual variations of carbon cycling parameters in Arctic and temperate Norwegian fjords

Omar A.M., Botnen H., Skjelvan I., de Lange T., Reggiani E., Falck E., Aspalin L., Olsen A. and Johannessen T.

Coastal seas exchange energy and matter with terrestrial, oceanic, and atmospheric reservoirs. They host strong biological activity fuelled by inputs of nutrients from the aforementioned reservoirs and play a significant role in marine carbon biogeochemistry. Additionally, due to influence through several different boundaries, carbon cycle parameters in the coastal ocean exhibit much higher variability compared open oceans, and they are thought to be more vulnerable to climate change and ocean acidification. We will present results from an on-going study on the marine carbon cycling in a number of Norwegian fjords located both in high and temperate latitudes. Preliminary analyses of data obtained from these areas, by voluntary observing ships and scientific cruises, reveal exceptionally high variability both in time and space. The seasonal variability seems to be controlled mainly by extensive biological activity, fresh water input as well as temperature, and the fjords are under-saturated relative to atmospheric CO₂ throughout the year. Four years long time series (2005-2009) from western Norway fjords reveals pH and omega aragonite values ranging between 8.04-8.30 and 1.54 – 2.68, respectively, with substantial year-to-year variations but no remarkable trend.

Keywords: Fjords, ocean acidification, carbon cycling.

Poster presentation

Comparison of seven packages that compute ocean carbonate chemistry

Orr J., Epitalon J.-M., and Gattuso J.-P.

To study ocean acidification and the carbon cycle, marine scientists often use two measured or modeled carbonate system variables to compute others. These carbonate chemistry calculations, based on well-known thermodynamic equilibria, are now available from seven public packages. We compared results from these packages using common input data and the sets of equilibrium constants. With the set of constants recommended for best practices, all packages agree within ± 0.00025 units for pH and ± 0.5 $\mu\text{mol/kg}$ for CO_3^{2-} , while six packages agree within ± 0.2 μatm for pCO_2 in terms of zonal-mean surface values. One package differs significantly for computed pCO_2 , underestimating surface values by up to 1.4 μatm . A second package diverges significantly but only in warm deep waters as found in the Mediterranean Sea. Despite general agreement between current packages, agreement was much worse with outdated versions, e.g., differences reached up to 2.5 μatm in pCO_2 , 1.4 $\mu\text{mol/kg}$ in CO_3^{2-} , and 0.007 units in pH for surface zonal means when using the best-practice constants. With more recent formulations for K1 and K2 designed to cover a wider range of salinities, packages disagree more, e.g., by 8 μatm in pCO_2 , 1 $\mu\text{mol/kg}$ in CO_3^{2-} , and 0.006 units in pH under typical surface conditions. Those discrepancies stem from packages using different sets of coefficients for the corresponding salinity dependence of the new formulations. Tests with a new publicly available package designed for ocean models demonstrates that (1) two common model approximations lead to small but significant errors in the deep ocean, (2) the common modeling practice of using practical alkalinity instead of total alkalinity (neglecting nutrient alkalinity) leads to biases in high-latitude surface pCO_2 of up to 12 μatm , and (3) the new formulation for total boron in the ocean increases surface pCO_2 by 4 μatm everywhere. Ocean models that use practical alkalinity and the old boron formulation may underpredict the modern depth of the aragonite saturation horizon by 100 m in the North Atlantic and by up to 300 m in the Southern Ocean.

Keywords: acidification, carbon, carbonate chemistry, model, comparison

Oral presentation

The Surface Ocean CO₂ Atlas (SOCAT) community effort: outlook for versions 3 and 4

Pfeil B., Bakker D.C.E., Olsen A., Hankin S., O'Brien K., Smith K., Jones S., Kozyr A. and all SOCAT contributors

The Surface Ocean CO₂ Atlas (SOCAT) project is an international effort providing a global surface ocean CO₂ data set with regular updates. SOCAT brings together, in a common format, all publicly available fCO₂ data for the surface oceans. SOCAT has a standardized data format and uniform quality-control is applied to the data and metadata. The first version of the SOCAT data set was made public in 2011 via www.socat.info and SOCAT version 2 was released in 2013. It is the world largest data product of its kind - containing more than 10 million fCO₂ measurements between 1968 and 2011 from 2660 data sets. SOCAT serves a wide range of user communities and two distinct data products are made available with each public release:

- 1) a 2nd level quality controlled global surface ocean fCO₂ data set following agreed procedures and quality control review by regional teams, and
- 2) gridded SOCAT products of monthly surface water fCO₂ means consisting of a 1° x 1° global grid with no temporal or spatial interpolation, and a similar 1/4x1/4 degree grid representing the continental margins.

The SOCAT group is currently working on the third version which is planned for release to the public in 2015. Version 3 with data as recent as 2013 is expected to contain more than 13 million fCO₂ measurements from more than 3000 data sets. SOCAT version 3 will also include data from alternative sensors such as CARIOCA drifters and SAMI sensors.

SOCAT version 4 is subject to an automation process that is designed to minimize the efforts required of data contributors and SOCAT team members who perform quality control. The system will assist individual scientists, who contribute new cruise data, by providing automated "sanity checks" of their data and metadata, and by providing data visualizations that include the ability to see the new observations in the context of historical observations from the same region and season. Some of the automation features will be tested and used for data entry of version 3.

The Global Carbon Project is using SOCAT for its 2013 Global Carbon Budget (Le Quéré et al., 2013). The GCP will get access to public data submitted to SOCAT version 3, in particular for the years 2012 and 2013 for its 2014 budget. The GCP team will use recalculated fCO₂ data in a uniform format, but without the full SOCAT version 3 quality control for their 2014 Global Carbon Budget.

Keywords: carbon dioxide, CO₂, SOCAT, climate change

Oral presentation

Spatiotemporal variability of $\delta^{13}\text{C}$ -DIC in surface ocean: Observations versus Models

Racapé, V., Metzl, N., Pierre, C., Reverdin, G., Bopp, L., Tagliabue, A. and Roche, D. Presented by [Lo Monaco C.](#)

The stable isotopic composition of dissolved inorganic carbon ($\delta^{13}\text{CDIC}$) in the ocean is a useful semi-conservative tracer for various oceanic analyses (e.g. water masses, paleo-circulation) and for global carbon studies (e.g. constraining the global carbon budget and the processes of CO_2 exchange). The mean annual large scale distribution of this tracer in the ocean is now relatively well documented at surface and at depth, but its temporal variability still needs to be appraised. Based on new observations collected from the late 1990s to 2012, this study describes and interprets the seasonal, interannual and decadal variability of $\delta^{13}\text{CDIC}$ in three oceanic regions: the North-Atlantic subpolar gyre (NASPG), the gulf of Guinea and the Southwestern Indian Ocean. In the surface waters of these regions, the $\delta^{13}\text{CDIC}$ seasonal amplitude varies from 0‰ to 1‰ and depends on the local balance between the biological activity and ocean dynamics. Although negligible in the short-term, the air-sea CO_2 exchange includes a large anthropogenic contribution, which modifies $\delta^{13}\text{CDIC}$ on longer timescales (oceanic Suess effect), but this feature can be masked by natural variability.

$\delta^{13}\text{CDIC}$ has been included in oceanic models to better understand its spatio-temporal variability, to evaluate past, present and future changes in global carbon cycle, as well as to reproduce past ocean circulation. These simulations have compared their results to $\delta^{13}\text{CDIC}$ observations collected over the period 1970-1990 and have not constrained their seasonal $\delta^{13}\text{CDIC}$ cycle, which is underpinned by important biological, chemical and physical processes. To that end, our observations are compared to NEMO-PISCES and ILOVECLIM models. We find that the $\delta^{13}\text{CDIC}$ seasonal cycle is under-estimated 2 or 3 times by these models, particularly in region of enhanced biological activity. Our analysis suggests that this shortfall results from the parameterisation of primary production in the model and require to be revised. An underestimate of the $\delta^{13}\text{CDIC}$ seasonal cycle could impact on the vertical profiles and modify the $\delta^{13}\text{CDIC}$ values in depth, suggesting thus to estimate the potential consequence of such variation on the gradient surface-depth.

Keywords: carbon 13, seasonal cycle, model comparison

Oral presentation

Decadal acidification in the water masses of the Atlantic Ocean

Ríos A.F., García-Ibáñez M.I., Fajar N.M., Velo A., Padin X.A., Wanninkhof R., Steinfeld R. and Pérez F.F.

Global ocean acidification is an expected consequence of increasing atmospheric CO₂. We present direct observations of the recent decreasing pH in the water masses of the Atlantic Ocean (50°S - 36°N) from 1993-4 to 2013. The highest pH changes (ΔpH) were principally in the upper (1000-1200 m) layers where the maximum change (-0.051 ± 0.003) was observed at the Subpolar/Subtropical South Atlantic (50°S-26°S) in the layer occupied by South Atlantic Central Water. Below 1000-1200 m the ΔpH are progressively decreasing showing a significant minimum increasing the differences from south to north (-0.005 to -0.007) in the layer occupied by lower Circumpolar Deep Water and lower North Atlantic Deep Water. Significant ΔpH were also observed associated to the Antarctic Bottom Water with slight higher values (-0.009 ± 0.008) with similar magnitude to the Antarctic Intermediate Water (-0.010 ± 0.010). Anthropogenic and non-anthropogenic contributions to the ΔpH were estimated to evaluate the changes due to the anthropogenic uptake ($\Delta\text{pH}_{\text{ant}}$) and to natural processes such as ventilation and mineralization of the organic matter ($\Delta\text{pH}_{\text{nat}}$). The $\Delta\text{pH}_{\text{ant}}$ were estimated with the anthropogenic carbon changes ($\Delta\text{C}_{\text{ant}}$) obtained with a method of back-calculation. These $\Delta\text{pH}_{\text{ant}}$ values were checked with the $\Delta\text{C}_{\text{ant}}$ calculated with the TTD method where no carbon is used in the estimate. A very good correlation ($r^2 = 0.93$) was obtained with a rate of $\Delta\text{pH}_{\text{ant}} -0.0019\pm 0.0001$ by $\Delta\text{C}_{\text{ant}}\text{-TTD}$. In the same way the $\Delta\text{pH}_{\text{nat}}$ was also checked against nitrate changes (ΔNO_3) that seems to explain an 80% of the mineralization process ($r^2 = 0.80$) with a rate of $\Delta\text{pH}_{\text{nat}} -0.0015\pm 0.0002$ by ΔNO_3 .

Keywords: acidification, pH, anthropogenic-CO₂, water masses, Atlantic

Oral presentation

Data-based sea-air CO₂ flux estimation - The Surface Ocean pCO₂ Mapping intercomparison (SOCOM)

Rödenbeck C., Bakker D.C.E., Iida Y., Jones S., Landschützer P., Metzl N., Nakaoka S.-I., Olsen A., Park G.-H., Sasse T., Schuster U., Valsala V. and Zeng J.

Measurements of surface-ocean carbon content, such as the pCO₂ observations collected in the Surface Ocean CO₂ Atlas (SOCAT), contain spatially and temporally explicit information about the sea-air CO₂ exchange. In order to map the point data into continuous spatio-temporal fields, a variety of methods has been developed by different groups. As the chosen approaches span a wide range of complexities from statistical interpolation, regression, neural networks, and data assimilation into process models, they comprise interesting complementarity, for example in the different weights given to individual input data streams, or in whether they use model-based or generic relationships between carbon and driving variables. The SOCOM initiative aims (1) to exploit this complementarity to learn more about the ocean biogeochemical signals and how they can be retrieved from different information sources, and (2) ultimately to provide a "best guess" CO₂ flux estimate from pCO₂, DIC, or other data, including an assessment of its robustness/limits. The contribution will present the ensemble in terms of their spatial patterns, biome-specific temporal variations, and comparison to independent data. Robust features will be identified.

Keywords: sea-air CO₂ flux, pCO₂ data, mapping

Oral presentation

What can SOCAT pCO₂ observations and atmospheric oxygen observations tell about ocean-atmosphere CO₂ flux variability?

Rödenbeck C., Bakker D.C.E., Metzl N., Olsen A., Sabine C., Cassar N., Reum F, Keeling R. F., and Heimann M.

A temporally and spatially resolved estimate of the global sea-air CO₂ flux is presented, obtained by fitting a data-driven diagnostic model of ocean mixed-layer biogeochemistry to surface-ocean CO₂ partial pressure data from the SOCAT data base. The estimated seasonality is well-constrained from the data in most regions, and compares well to the widely used monthly climatology by Takahashi et al. (2009). Comparison to independent carbon data tentatively supports the slightly higher seasonal variations in our estimates in some areas. According to statistical diagnostics, SOCAT data are dense enough to estimate inter-annual variations in the tropical and Northern Pacific and in the Northern Atlantic. The estimated anomalies are largest in the tropical Pacific, and strongly tied to ENSO. Anomalies in the Eastern tropical Pacific occur about 6 months later than in the West. Extending the diagnostic model to link carbon variability to variability in nutrients and oxygen, it offers a way to implement multiple data constraints on sea-air CO₂ fluxes. As a prerequisite towards this goal, we demonstrate that the seasonality estimated from the pCO₂ data is consistent with an independent seasonal climatology of the surface-ocean PO₄ concentrations. Likewise, tropical inter-annual signals estimated from SOCAT data are compatible with signals from atmospheric oxygen data, both supporting the SOCAT-based estimates and demonstrating the potential of atmospheric oxygen data to constrain under-sampled areas.

Keywords: sea-air CO₂-flux, pCO₂-data, oxygen-data, IAV

Poster presentation

A preliminary attempt to estimate surface ocean pH from satellite observations

Sabia R., Fernández-Prieto D and Donlon C.

The surface ocean currently absorbs approximately one third of the excess carbon dioxide (CO₂) injected into the atmosphere from human fossil fuel burning and deforestation, mitigating the impact of global warming and climate change. However, this anthropogenic CO₂ absorption by seawater determines a reduction of both ocean pH and the concentration of carbonate ion. The overall process is commonly referred to as Ocean Acidification (OA), and is nowadays gathering increasing attention as one of the major foci of climate-related research, having profound impact not only at scientific level, but also in the socio-economic dimension.

Growing international efforts are being devoted to develop a coordinated strategy for monitoring OA, with an eager need for global and frequent observations of OA-relevant parameters; yet, the datasets acquired are currently mostly relevant to in-situ measurements, laboratory-controlled experiments and models simulations. Remote sensing technology can be integrated by providing synoptic and frequent OA-related observations, upscaling and extending in-situ carbonate chemistry measurements on different spatial/temporal scales, despite the preliminary products developed so far are only regional, empirical or derived with a limited variety of satellite datasets.

Within this context, the purpose of this study is to quantitatively and routinely estimate surface ocean pH by means of satellite remote sensing observations. The thematic objectives are 1) to develop new algorithms and data processing strategies to overcome the relative immaturity of OA satellite products currently available, and 2) to produce a global, temporally evolving, suite of relevant satellite-derived data.

This will be performed by exploiting the information content of Ocean Colour (OC) data, Sea Surface Temperature (SST), Wind Speed (WS) and Sea Surface Salinity (SSS) parameters (with an emphasis on the latter, as the recent addition to satellite products). A proper merging of these different satellites datasets will allow to compute at least two independent proxies among the seawater carbon dioxide system parameters: namely, the partial pressure of CO₂ in surface seawater (pCO₂); the total alkalinity (AT) and the total Dissolved Inorganic Carbon (DIC). Through the knowledge of these parameters, the final objective is to come up with the currently best educated guess of the surface ocean pH.

After the evaluation of the optimal data processing at the spatial and temporal scale desired, an overall validation plan will be instrumental to verify the consistency, accuracy and robustness of the satellite datasets produced, by quality-controlling the satellite products against in-situ measurements and modelling outputs.

The innovation of this study lies mainly in the effort of unifying fragmented remote sensing studies and generating a novel value-added satellite product: a global and frequent surface ocean pH “cartography”, bridging the gap between the satellite and the IMBER and SOLAS process studies communities, and benefiting from their cross-fertilization and feedback.

Keywords: Acidification; remote sensing; pH; ocean salinity

Poster presentation

The link between eutrophication and acidification in the Black Sea: a modelling study

Salihoglu B., Arkin S.S., Oguz T. and Fach B.A.

The carbonate system properties of the Black Sea inner basin vertical profiles are compressed (upper 100 m) versions of their open ocean counterparts (upper 1000 m) because of very strong stratification confined into a shallow upper layer above the pycnocline. In addition, concentrations of its properties are much higher at all depths in the Black Sea than those observed in the oceans, as well as many other semi-enclosed and marginal sea systems. A three-dimensional coupled physical–biogeochemical model is used to elucidate the major processes controlling the carbonate system properties of the interior Black Sea. During the present post-eutrophication phase of the recent biogeochemical history of the Black Sea, high total alkalinity (TA), dissolved inorganic carbon content (DIC ~ 3.0 mmol kg⁻¹) and partial pressure of carbon dioxide (pCO₂ > 1000 µatm) accompanied with a very strong density stratification (> 3 kg m⁻³) promote a distinct two layer structure within the upper 100 m above the anoxic interface. Simulation results show that the upper 20m layer possesses an almost zero annual-mean surface CO₂ flux (0.04 mmol m⁻² d⁻¹) into the sea albeit strong seasonality in the carbonate system properties driven by changes in temperature, mixing, and biological processes. The average pCO₂ concentration in this layer exceeds pCO₂atm most of the year due to the contribution from its internal resources. Below 30m, heterotrophic processes generate a strong transitional zone with a thickness of 20m. This is followed by a roughly 50m thick layer extending down to the anoxic interface with maximum pCO₂ and DIC concentrations and minimum pH values. Nitrogen and phosphorus peaks and oxygen depletion also characterize this layer. These subsurface properties show marked differences in respect to their structures compared to early-eutrophication phase simulations.

Keywords: carbonate system, Black Sea, biogeochemical model

Poster presentation

Variability of the northern hemisphere air-sea CO₂ flux over the last decade

Schuster U., Watson A.J., Nakaoka S.-I. and Nojiri Y.

Measurements of sea surface pCO₂ and related parameters have been done in the North Atlantic and North Pacific for over a decade, using Voluntary Observing Ships, offering the unique opportunity of studying northern hemisphere variability.

Changes in the North Atlantic Oscillation (NAO) are known to induce shifts in the path of the Gulf Stream, leading to changes in sea surface temperature (SST) in the vicinity of such shifts. SST changes can be expected to thermodynamically lead to changes in sea surface pCO₂. However, a similar relationship between sea surface pCO₂ and the NAO index is not always found. In the North Pacific, the influence of changes in the Pacific Decadal Oscillation (PDO) on sea surface pCO₂ are different, and no change in the correlation between sea surface pCO₂ and SST is found.

Maps of sea surface pCO₂ and air-sea CO₂ flux are being produced, together with uncertainties being identified. We will present the total northern hemisphere air-sea CO₂ flux and its variability over the decade from 2002 to 2012, and the mechanistic biological, chemical, and physical, and climate mode drivers of identified variability.

Keywords: air-sea CO₂ flux, northern hemisphere, variability

Poster presentation

Observational indicators of change to the Southern Ocean carbon system from the Drake Passage Time Series Experiment

Sweeney C., Takahashi T., Newberger T., Munro D.R., Lovenduski N.S., Stephens B., Sprintall J. and Chereskin T.

Increased winds speeds and a net poleward shift in wind speed maximum has led models to the conclusion that the Southern Ocean's ability to absorb the rapid increase in atmospheric CO₂ has decreased with time due to increased overturning of deep waters to the surface. Over the last 13 years the Drake Passage Times Series Experiment has provided an opportunity to closely monitor these changes with more than 260 transects across the Drake Passage measuring surface water pCO₂. By leveraging discrete observations of DIC, salinity, temperature, nutrients and the C-14 and C-13 isotopes of DIC from historical data and two hydrographic cruises and ~6 transects each year we are able to not only monitor changes in net community production over the last 13 years but possible changes in overturning circulation over the last 30 years. Beyond direct observations of changes in the ocean carbon system this dataset offers a unique opportunity to validate trends and magnitudes estimated by satellite-based productivity algorithms and to improve understanding of the role of this region in the global carbon cycle.

Keywords: CO₂ , Southern Ocean, Carbon, NCP

Oral presentation

Transient tracer data in the GLODAPv2 data collection to estimate the decadal increase of anthropogenic CO₂ in the global ocean

Tanhua T., Steinfeldt R. and Jeansson E.

With the publication of the GLODAPv2 data collection a large, quality controlled, data set of transient tracer data is available. We use this data collection to determine the changes in ocean ventilation and uptake of anthropogenic CO₂ (C_{ant}) on a global scale. For this we use available SF₆, CFC-12 and CFC-11 data in the transit time distribution (TTD) concept. This provides an independent estimate of C_{ant} uptake by the ocean during the last decades (1990s-2000s) that will be compared with estimates based on other, carbon based, methods. Changes in ventilation have previously been observed for different parts of the ocean, and we now use this new data resource to systematically evaluate decadal (?) changes in ocean ventilation, mainly along repeat hydrographic sections.

Keywords: transient tracers, anthropogenic carbon, GLODAPv2

Oral presentation

Coastal eutrophication studied in situ using multi-parameter platforms

Tengberg A., Atamanchuk D., Kononets M., Hall P., Viktorsson L. and Waldmann C.

With the Baltic Sea and neighboring areas in focus this presentation will give examples on how coastal ecosystems have been studied in-situ using different types of multi-parameter platforms including: moored instruments, on-line observatories, bottom landers and ferry box systems. Coupling between physical factors-oxygen-nutrients-pCO₂/pH/DIC (Dissolved Inorganic Carbon) will be discussed and the latest measurement technology described.

Keywords: Coastal, Eutrophication, In situ technology, Carbon

Oral presentation

Spatial and temporal variability in satellite estimates of net community production over the Atlantic basin.

Tilstone G., Robinson C. and Serret P.

The recent warming of the Earth system has important impacts on carbon cycling in the ecosystem. Marine photosynthesis and respiration rates are the engines in regulating climatically active gases. There is, however ongoing debate as to whether the oligotrophic oceans are predominantly net autotrophic and acting as a CO₂ sink, or net heterotrophic and therefore acting as a CO₂ source to the atmosphere. This is hard to quantify, both spatially and temporally, due to the sparseness of in situ observations. There has been a concerted effort to derive accurate estimates of phytoplankton photosynthesis and primary production from satellite to fill these gaps, however there have been few satellite estimates of net community production. In this paper the accuracy of number of approaches to estimating net community production from satellite data are assessed in 15 provinces of the Atlantic Ocean, from the sub-Arctic waters of the North Atlantic to the South Atlantic Gyre. For the most accurate algorithm(s), a ~13-year time series of net community production is generated to assess spatial and temporal trends in net community production over the Atlantic Ocean. The North Atlantic sub-tropical and tropical Gyres remained predominantly net autotrophic from 1998 to 2010, suggesting that despite recent warming in the northern hemisphere it still remains a net sink for CO₂. The South Atlantic sub-tropical Gyre and subtropical convergence zone fluctuate from net autotrophic in austral to net heterotrophic in austral winter, suggesting that recent warming in these provinces is altering the system towards a CO₂ source in austral winter. Variations in net community production in the northern and southern hemisphere were anti-correlated with the multivariate ENSO index, whereas in the tropics and subtropics, there was a positive correlation with ENSO. The results are discussed in relation to decadal oscillations in net community production in the Atlantic Ocean and their implications for carbon cycling in the marine ecosystem.

Keywords: Net community production, Atlantic Ocean, ENSO

Oral presentation

Basin-scale distribution and seasonal to inter-annual variation of dissolved inorganic carbon over the North Pacific

Yasunaka S., Nojiri Y., Nakaoka S.-I., Ono T., Mukai H., and Usui N.

Monthly distribution maps of surface dissolved inorganic carbon (DIC) were produced over the North Pacific from 2002 to 2008. The estimated DIC agrees well with the observational DIC at research vessel based time-series stations with a root mean square error of 10.2 $\mu\text{mol/kg}$. Spatial distribution of DIC mean state corresponds with sea surface salinity distribution and ocean circulation. DIC seasonal variation is characterized by 10 areal clusters, and DIC decrease from the end of winter to summer was captured; more than 120 $\mu\text{mol/kg}$ in the northwestern part, while less than 30 $\mu\text{mol/kg}$ in the subtropics. The DIC decreases from March to July subtracting effects of air-sea CO_2 flux and salinity change can be considered as net community production (NCP); more than 15 $\text{mmolC/m}^2/\text{day}$ in the boundary region between the subtropics and the subarctic to the west of the date-line, more than 8 $\text{mmolC/m}^2/\text{day}$ in the coastal region of the subarctic, and 4~10 $\text{mmolC/m}^2/\text{day}$ in the offshore region of the subarctic. The NCP spatial distribution corresponds well to 20~30% of the satellite derived net primary production. Inter-annual variation of DIC in the subarctic is caused by changes of salinity, vertical mixing, and biological production. Whereas, DIC variation in the mid-latitudes and the subtropics is caused by changes of salinity and air-sea flux. The Pacific Decadal Oscillation induces the dominant inter-annual variation of the North Pacific carbon cycle via changes of the ocean-atmospheric condition.

Keywords: North Pacific dissolved inorganic carbon

Poster presentation

Session A2: Synthesis of ecological and biogeochemical variability

Oral Presentations

Thursday 26 June, 14:00-15:30 Parallel session 7

Room K4

Time	Presenter	Title
14:00-14:30	Marañón, Emilio	Resource supply overrides temperature as a controlling factor of marine phytoplankton growth
14:30-14:50	Guo, Xinyu	Downstream transport of nutrient transport by the Kuroshio and its temporal and spatial variations
14:50-15:10	Coppola, Laurent	Dynamics of the dissolved oxygen in the NW Mediterranean Sea (DYFAMED site)
15:10-15:30	Migon, Christophe	Seasonal and decadal variability of nutrient concentration: data from the DYFAMED station (Ligurian Sea)

Friday 27 June, 10:30-12:00 Parallel session 8

Room K4

Time	Presenter	Title
10:30-11:00	Serret, Pablo	Longitudinal trend towards metabolic balance in the North Atlantic oligotrophic gyre
11:00-11:20	Soltwedel, Thomas	Time-series studies in a gateway to the Arctic Ocean: impact of Climate Change vs. natural variability at the deep-sea observatory HAUSGARTEN
11:20-11:40	Wallhead, Phil	Long-term variability of phytoplankton carbon biomass in the Sargasso Sea
11:40-12:00	Gogou, Alexandra	Export of carbon, nitrogen, ballast minerals and coccolithophores to the mesopelagic and bathypelagic layers of the 'NESTOR' times-series station (Ionian Sea, deepest Mediterranean site)

Poster Presentations

Wednesday 25 June, 17:30, Poster Session 2

ID	Presenter	Title
A2.P1	Haugan, Peter	Fixed point Open Ocean Observatory network (FixO3): Multidisciplinary observations for a better understanding of global change
A2.P2	Garcia Garcia, Francisca	Cytometric diversity of marine bacterioplankton: a 10-year interannual study in the Southern Bay of Biscay
A2.P3	Li, Qian	Biological Effects of Iron and Nutrients Addition in the Western Pacific Ocean and China Seas
A2.P4	Yasunaka, Sayaka	Monthly maps of sea surface nutrients in the North Pacific: Basin-wide distribution and seasonal to interannual variations

Dynamics of the dissolved oxygen in the NW Mediterranean Sea (DYFAMED site)

Coppola L., Prieur L., and Legendre L.

Recent studies evidenced that climatic changes does not only occur at centenary and millenary scales, but may also occur at much shorter time scales. This is particularly important for the Mediterranean Sea, where the spatial and temporal scales are one order of magnitude smaller than in the global ocean. Since the late 80's a rapid and extended change of the deep water formation cell in the eastern basin has been observed (Eastern Mediterranean Transient event). More recently, modifications of the deep water mass properties have been also observed in the western basin suggesting a propagation of the EMT event (so called the Western Mediterranean Transient) with a probable impact on marine ecosystems. This change shows the importance for a continuous monitoring of the Mediterranean circulation in strategic area to estimate the impact of the water circulation on biogeochemistry cycles. The DYFAMED time series (Ligurian Sea) represents one of the longest oceanic time series in the Mediterranean Sea where water mass changes have been already observed (Marty and Chiaverini, 2010). To detect hydrodynamic change, T and S parameters are currently used. Here we propose to use the dissolved oxygen concentrations, which has been acquired during the DYFAMED time series from 1993 to 2012 (through the FP7 project EUROSITES 2008-2011 and the national program MOOSE since 2010) to detect deep convection event, water mass ventilation and intrusion of new water mass that occurred in the DYFAMED area over the last 20 years.

Keywords: Dyfamed, oxygen, LIW, WMDW

Oral presentation

Cytometric diversity of marine bacterioplankton: a 10-year interannual study in the Southern Bay of Biscay

Garcia Garcia F.C., Alonso-Sáez L., Morán X.A.G. and López Urrutia Á.

The application of molecular methods to marine ecology studies in the last decades has completely changed our view of the patterns of diversity and distribution of microorganisms in the ocean. However, molecular approaches are expensive and time-consuming when applied on a very large number of samples, restricting their use in large-scale studies. Flow-cytometry, on the other hand, allows an efficient processing of a large number of plankton samples in a relatively short period of time. In this sense, the use of single-cell measurements by flow-cytometry for diversity purposes would be a great advance. In marine ecosystems, this concept has been introduced as 'cytometric diversity', and it has been so far applied to the study of phytoplankton communities.

Here, we present a new approach to study cytometric diversity patterns in marine bacterioplankton. We compared variations in bacterial diversity and community structure by using a phylogenetic marker (16S rRNA gene, analysed by pyrosequencing) and cytometric properties of bacterial populations in samples collected in surface coastal waters along 3-seasonal cycles. Additionally, we calculated cytometric diversity estimates for marine bacteria using a 10-year time series database in the Cantabrian Sea to assess interannual changes in bacterial community structure.

Even if both approaches clearly have different levels of resolution, variations in the diversity of bacterial communities detected by the molecular and flow-cytometry approaches were significantly correlated in our environmental dataset. These results suggest that the analysis of cytometric diversity can provide relevant insights into the temporal patterns in the structure of bacterial communities. The analysis of bacterial cytometric diversity throughout the water column over the 10-years time-series revealed that mixing has an important role in explaining the cyclical pattern of bacterial diversity found in coastal systems, with maxima in winter and minima in summer.

Keywords: Bacteria, community, diversity, flow-cytometry, 16SrRNA, seasonality

Poster presentation

Export of carbon, nitrogen, ballast minerals and coccolithophores to the mesopelagic and bathypelagic layers of the 'NESTOR' times-series station (Ionian Sea, deepest Mediterranean site)

Gogou A., Trintaphyllou M., Stavrakakis S., Krasakopoulou E., Karageorgis A., Parinos C., Dimiza M., Assimakopoulou G. and Lykousis V.

The Eastern Mediterranean (EM) is an oligotrophic sea that presents unusually high N:P molar ratio (up to 28:1) and depleted $\delta^{15}\text{N}$ values in nitrates and suspended material compared to other oceanic settings (Emeis et al, 2010). Aiming to investigate the significant biogeochemical features and provide new insights on the sources and cycles of carbon and nitrogen in the region, we have examined long-term records of downward fluxes for Corg, N, $\delta^{13}\text{C}_{\text{Corg}}$ and $\delta^{15}\text{N}$, along with the associated ballast minerals (opal, lithogenics and CaCO_3) and coccolithophores (main calcifying primary producers), as recorded in sinking particulate matter intercepted by time-series sediment traps. A mooring line was deployed from 2006 to 2010 at 5 successive water column depths (700, 1200, 2000, 3200 and 4300 m) in the SE Ionian Sea, where the deepest part of the Mediterranean Sea is located ('NESTOR' site). Temporal variations of the mass flux showed similar seasonal signal at all sampling depths with higher values in spring - summer and lower in autumn – winter (Stavrakakis et al., 2013). Changes in the main constituents of the mass flux (organic carbon, carbonates, opal, and lithogenic matter) largely followed the same temporal variability with total mass flux, revealing mechanisms of rapid vertical (top-down) transport from 700 m down to 4300 m depth. Primary productivity shows two maxima during late winter/early spring and late spring/summer, as witnessed by the organic carbon, carbonate, and opal fluxes in the mesopelagic and bathypelagic layers, whereas the influence of dust inputs is evidenced by enhanced lithogenic fluxes occurring during spring and summer. A gradual increase of fluxes during the time frame of the experiment, marked also by a decrease in C:N and increase in $\delta^{13}\text{C}$ values. Enhancement of surface productivity towards the end of the experiment is possibly related to the development of an anticyclonic mode in the Adriatic-Ionian BIOS system, along with variations in the intensity and position of the neighbouring Pelops anticyclonic gyre, which appears to affect the upwelling of intermediate, nutrient-rich waters. The analysis of coccolithophore weight from the sediment trap series, in particular *Emiliania huxleyi* coccoliths, provide evidence of seasonal variability in coccolith weight, mirroring seasonal changes in the surface ocean carbonate system associated with air-sea CO_2 fluxes, as has been observed before in other EM sites (Triantaphyllou et al., 2010). Combination of estimated satellite and algorithm-generated primary production data, calculated POC fluxes out of the euphotic layer and POC fluxes measured by sediment traps at the mesopelagic and bathypelagic layers of the NESTOR site during our 4-year experiment, reveal that only a small portion of primary production (0.15 to 1.87%) reach at 4300 m depth, ranging from 0.13 to 1.64 $\text{gC m}^{-2} \text{y}^{-1}$.

Keywords: Eastern Mediterranean, biogeochemical fluxes, carbon sequestration

Oral presentation

Downstream transport of nutrient transport by the Kuroshio and its temporal and spatial variations

Guo X., and Zhu X.

Strong western boundary currents carry large quantities of water and heat, as well as a variety of dissolved materials, including nutrients and can have a significant influence on the climate and marine ecosystems. Quantitation of nutrient transport by the western boundary current is an important step to understanding the nutrient element cycle at the basin-scale. Pelegrí and Csanady (1991JGR) and Pelegrí et al. (1996JO) reported a subsurface maximum in nutrient flux and nitrate transport in the order of 1000 kmol s^{-1} in the Gulf Stream, and proposed the presence of a nutrient stream along the Gulf Stream, from upstream to downstream areas.

The Gulf Stream's North Pacific counterpart, the Kuroshio, is expected to have the same nutrient transport function as the Gulf Stream. Based on data from 88 cruises from 1987 to 2009 at a section across the Kuroshio in the East China Sea, we obtained a long-term averaged nutrient flux of $170.8 \text{ kmol s}^{-1}$ and demonstrated a subsurface maximum core at 400 m depth (Guo et al., 2012JGR). The value is, however, less than that observed in the Gulf Stream. Observations there indicated that the amount of nitrate transported may significantly increase along this stream (Pelegrí and Csanady, 1991JGR; Pelegrí et al., 1996JO; Williams et al., 2011GBC). Therefore, we also need to investigate the downstream change of nutrient transport by the Kuroshio 1) to confirm the presence of the "Kuroshio nutrient stream" from its upstream to downstream regions and 2) to understand the processes responsible for the downstream variations in nutrient transport by the Kuroshio.

Based on absolute geostrophic velocity, which was calculated using repeated hydrographic data from 39 cruises from 2000 to 2009 by the Japan Meteorological Agency and nitrate concentrations measured in the same areas from 1964 to 2009, we obtained the temporally averaged nitrate flux and nitrate transport of four sections across the Kuroshio from the East China Sea (upstream area) to an area south of Japan (downstream area).

The mean nitrate flux showed a subsurface maximum core with values of 9.6, 10.6, 11.2, and $10.5 \text{ mol m}^{-2}\text{s}^{-1}$ at above mentioned 4 sections, respectively. The depth of the subsurface maximum core is approximately 400, 500, 500, and 400 m, respectively. The mean downstream nitrate transport is 204.8, 165.8, 879.3, and $1230.4 \text{ kmol s}^{-1}$, respectively. The transport of nutrients in these sections suggests the presence of the Kuroshio nutrient stream from its upstream to downstream regions and an apparent downstream increase of nutrient transport, which has two sources. One is the nitrate carried by the Kuroshio recirculation that returns to the Kuroshio from its southern area. The other is the along-stream change of nitrate concentration, which is caused by diapycnal mixing and biological processes occurring along the Kuroshio. A budget calculation indicates that the along-stream change of nitrate concentration is as important as the Kuroshio recirculation in the upper layers ($<26.5\sigma\theta$).

Keywords: Nutrient transport, Kuroshio

Oral presentation

Fixed point Open Ocean Observatory network (FixO3): Multidisciplinary observations for a better understanding of global change

Lampitt R., Cristini L., Cardin V., Petihakis G., Robe. Presented by Haugan, P.

The Fixed point Open Ocean Observatory network (FixO3) seeks to integrate the 23 European open ocean fixed point observatories and to improve access to these key installations for the broader community. These will provide multidisciplinary observations in all parts of the oceans from the air-sea interface to the deep seafloor. Coordinated by the National Oceanography Centre, UK, FixO3 builds on the significant advances achieved through the previous Europe-funded FP7 programmes EuroSITES, ESONET and CARBOOCEAN. Started in September 2013 with a budget of 7 million Euros over four years the project has 29 partners drawn from academia, research institutions and SME's. In addition 12 international experts from a wide range of disciplines comprise an Advisory Board.

On behalf of the FixO3 Consortium, we present the programme that will be achieved through the activities of 12 Work Packages:

1. Coordination activities to integrate and harmonise the current procedures and processes. Strong links will be fostered with the wider community across academia, industry, policy and the general public through outreach, knowledge exchange and training.
2. Support actions to offer a) free access to observatory infrastructures to those who do not have such access, and b) free and open data services and products.
3. Joint research activities to innovate and enhance the current capability for multidisciplinary in situ ocean observation.

Support actions include Transnational Access (TNA) to FixO3 infrastructure, meaning that European organizations can apply to free-of-charge access to the observatories for research and testing in two international calls during the project lifetime. The first call for TNA opens in summer 2014. More information can be found on FixO3 website (www.fixo3.eu).

Open ocean observation is currently a high priority for European marine and maritime activities. FixO3 will provide important data on environmental products and services to address the Marine Strategy Framework Directive and in support of the European Integrated Maritime Policy. The FixO3 network will provide free and open access to in situ fixed point data of the highest quality. It will provide a strong integrated framework of open ocean facilities in the Atlantic from the Arctic to the Antarctic and throughout the Mediterranean, enabling an integrated, regional and multidisciplinary approach to understand natural and anthropogenic change in the ocean.

Keywords: Fixed-point observations; multidisciplinary; European; Network

Oral presentation

Biological effects of iron and nutrients addition in the Western Pacific Ocean and China Seas

Li Q. and Jiao N. et al.

This study investigated the iron and nutrients limitation status along a transect in Western Pacific (WP) and South China Sea (SCS), with emphasis on responses of phytoplankton biomass, photosynthetic competency and picoplanktonic population abundance. Meanwhile, microbial community succession of both autotrophs and heterotrophs during the incubation was analysed at tropical WP station WP1 and WP2, where a fairly high photosynthetic competency (>0.5) of in situ phytoplankton community was observed despite the extremely oligotrophic conditions. Combining the active fluorescence (FRRF) parameter F_v/F_m , total amount of chlorophyll a (Chl a), Flow Cytometry (FCM) population numbers, High Performance Liquid Chromatography (HPLC) pigments and molecular approaches, a total of 22 nutrient enrichment bioassays were conducted during 3 cruises from 2008 to 2011. We report here a nutrient controlling progression from iron and nitrogen co-limitation at 160°E equatorial Pacific to nitrogen limitation in oligotrophic WP and SCS, suggested by the significant increase of total Chl a biomass, F_v/F_m and growth of picoplankton groups in corresponding treatments. Meanwhile, effects on community structure of both phytoplankton and heterotrophic bacteria of iron addition in the tropical oligotrophic WP, were manifested through promoting medium-large phytoplankton such as Chlorophyte and Diatom and bacterial species of Flavobacteria but inhibiting α -Proteobacteria.

Keywords: Iron enrichment, photochemical competency, community structure

Poster presentation

Resource supply overrides temperature as a controlling factor of marine phytoplankton growth

Marañón E., Cermeño P., Huete Ortega M., López Sandoval D.C., Mouriño Carballido B. and Rodríguez Ramos T.

The universal temperature dependence of metabolic rates has been used to predict how ocean biology will respond to ocean warming. Determining the temperature sensitivity of phytoplankton metabolism and growth is of especial importance because this group of organisms is responsible for nearly half of global primary production, sustains most marine food webs, and contributes to regulate the exchange of CO₂ between the ocean and the atmosphere. Phytoplankton growth rates increase with temperature under optimal growth conditions in the laboratory, but it is unclear whether the same degree of temperature dependence exists in nature, where resources are often limiting. Here we use concurrent measurements of phytoplankton biomass and carbon fixation rates in polar, temperate and tropical regions to determine the role of temperature and resource supply in the control of in situ biomass-specific production rates. We identify a biogeographic pattern in phytoplankton growth rate, which increases from the oligotrophic subtropical gyres to temperate regions and then coastal waters. This large-scale variability in phytoplankton growth is driven by changes in resource supply and appears to be independent of seawater temperature. The lack of temperature sensitivity of realized phytoplankton growth is consistent with the limited applicability of Arrhenius enzymatic kinetics when substrate concentrations are low. Our results suggest that, due to widespread resource limitation in the ocean, the direct effect of sea surface warming upon phytoplankton growth and productivity will be smaller than anticipated.

Keywords: phytoplankton, temperature, resource supply, growth, metabolism

Oral presentation

Seasonal and decadal variability of nutrient concentration: data from the dyfamed station (Ligurian Sea)

Pasqueron De Fommervault O., Migon C., D'Ortenzio F. and Coppola L.

The Mediterranean Sea is a relatively oligotrophic province characterised by a west-to-east gradient of increasing oligotrophy. In this Low Nutrient Low Chlorophyll (LNLC) environment, primary productivity depends to a large extent on the availability of macro-nutrients, i.e. nitrogen (N), phosphorus (P) and silicon (Si). Due to reduced dimensions, and specific external conditions (intense and contrasted land-based emissions of nutrients), the stoichiometry of the northwestern Mediterranean Sea results in peculiar N:P:Si molar ratios compared to the Redfield value. However, time-series data on nutrient dynamics are still scarce in the Mediterranean Sea. From 1991 to 2011, nutrient concentrations were continuously measured at the DYFAMED time-series (site located in the central Ligurian Sea, 28 nautical miles from Nice, 2350m deep, 43°25'N, 7°52'E), now in the framework of the national MOOSE network (Mediterranean Ocean Observing System for the Environment). Owing to the strong scattering of results, caused by various types of possible errors (uncertainty on measurements, approximations, change of operator, etc.), nutrient data underwent a quality control.

The “climatological” analyse permitted to evidence a clear reproducible patterns in relation to seasonal physical and biogeochemical processes. In winter, the convection homogenises nutrient concentrations along the water column, and triggers the subsequent phytoplankton bloom, in spring. In summer and autumn the stratification of the water column progressively increases and nutrients are consumed by biota. This is the oligotrophic season, resulting in typical surface-depleted profiles and deepening of the nutriclines. The seasonal variability of the chemical limitation was also exanimated. Data showed relatively high N:P ratios throughout the year, and a shift from nitrate (spring) to phosphate (summer and fall) limitation.

Due to the very short residence time of Mediterranean waters (15 years, approximately in the western basin), compared to those of the global ocean (500–1000 years), rapid environmental, climatic and meteorological changes around the western basin are capable of altering concentrations and molar ratios of nutrients at decadal time scales. The evolution of nutrient concentration profiles was examined over 20 years. It was observed, in deep water, a significant increase in the N:P ratio, presumably related to a decrease in phosphate concentration, while nitrate concentrations remains stable.

Keywords: Time series, DYFAMED, nutrients, Ligurian Sea

Oral presentation

Longitudinal trend towards metabolic balance in the North Atlantic oligotrophic gyre

Aranguren Gassis M., Serret P., Gist N. and Robinson C.

Quantifying the metabolic balance of plankton in oligotrophic regions is still a controversial issue in oceanography with great implications for global carbon balance calculations. We have compiled net community production (NCP) rates measured in the North Atlantic oligotrophic gyre for a decade, from the Atlantic Meridional Transect program and other projects. The analysis of the resulting database revealed a longitudinal trend in plankton community metabolism, from heterotrophy in the eastern margin of the gyre to balanced metabolism in the centre. This spatial variability implies that an average value of NCP cannot adequately describe the regional net metabolism, since calculating a mean relies on the assumption of spatial homogeneity.

Keywords: Metabolic balance. Plankton. North Atlantic gyre.

Oral presentation

Time-series studies in a gateway to the Arctic Ocean: impact of climate change vs. natural variability at the deep-sea observatory HAUSGARTEN

Soltwedel T., Bauerfeind E., Bergmann M., Hasemann C., Jacob M., Lalande C., Kraft A., Metfies K., Nöthig E.-M. and Schewe I.

The Long-Term Ecological Research (LTER) site HAUSGARTEN is located in Fram Strait, representing one of the most sensitive regions with regard to Climate Change in the North. The unique long-term record assessed at the observatory is one of the best data sets available to study Arctic marine ecosystem dynamics.

HAUSGARTEN represents a network of 20 sampling sites arranged along a bathymetric transect (300-5500m) and along a latitudinal transect following the 2500m isobath. Annual water and sediment sampling as well as the year-round deployment of moorings and free-falling systems, which act as local observation platforms, has taken place since 1999. Multidisciplinary research activities at HAUSGARTEN cover almost all compartments of the marine ecosystem from the pelagic zone to the benthic realm.

Time-series studies at HAUSGARTEN already exhibited trends from which, at the moment, we do not know whether these already indicate Climate Change induced lasting alterations of the system or simply reflect natural variability on multi-year time scales, e.g. in relation to variations in the Arctic Oscillation.

Water temperatures in the Fram Strait generally increased over the last years. For the period 1997-2012, there was a positive linear trend in Atlantic Water mean temperature of 0.1°C per year. A massive temperature increase was observed within the upper 500-1000m of the water column between the summers of 2005 and 2008. Records from moored instruments at the central HAUSGARTEN site (2500m water depth) between 1999 and 2013 showed a similar overall increase in water temperature at 2 m above the seafloor.

Water temperature as well as sea ice transport and melting showed to be the main factors influencing the amount and occurrence of the phytoplankton in Fram Strait. During the last decade, chlorophyll a biomass has slightly increased in the eastern part of the passage, whereas it was relatively constant in the colder western parts. Microscopic and molecular studies revealed a shift in micro- and nanoplankton populations from diatoms to *Phaeocystis pouchetii* and smaller flagellates. For the zooplankton, we observed a decrease in polar species and an increase in boreal species.

Alterations in planktonic assemblages affect the flux of organic matter (food/energy) to the seafloor. Analyses of various biogenic sediment compounds between 2000 and 2005 revealed a generally decreasing transfer of detritus to the seafloor and subsequently decreasing microbial biomass and bacterial richness in the sediments. A comparison of footage between 2002 and 2007 demonstrated a parallel decrease in megafaunal densities at 2500m water depth. Since then, we observed a reverse trend with increasing food availability at the seafloor and again increasing microbial biomass in the sediments. First results from photo/video surveys in 2011 showed again rising megafauna densities, probably reflecting a direct effect of (again) enhanced organic matter availability for the benthos.

The remarkably rapid response of the benthic community to variations in food/energy

Session A2: Synthesis of ecological and biogeochemical variability

supply is in contrast to earlier assumptions on the sensitivity of deep-sea ecosystems and obviously involves shifts in the species composition, thereby affecting benthic biodiversity as well as the functional diversity at the deep seafloor.

Keywords: Arctic, Marine Ecosystem, Long-term Observations, HAUSGARTEN

Oral presentation

Long-term variability of phytoplankton carbon biomass in the Sargasso Sea

Wallhead P.J., Garcon V.C., Casey J.R. and Lomas M.W.

The Bermuda Atlantic Time-series Study (BATS) provides rare insights into the interannual/decadal variability of the North Atlantic subtropical gyre ecosystem and biogeochemical fluxes. We used multiple regression to synthesize recent flow-cytometric data with long-term BATS “core” measurements, and thereby reconstruct taxon-specific phytoplankton carbon biomass over the last two decades. The reconstruction reveals an increasing trend (~3% per year) in total phytoplankton carbon, apparently driven by increasing nutrient supply from vertical mixing associated with a decreasing winter North Atlantic Oscillation index. Also, the reconstructed eukaryote biomass fraction shifted between ~45% in the early 1990s/late 2000s and ~70% in the late 1990s/early 2000s, possibly in response to shifts in the seasonal pattern of mixing which restructured the eukaryote community while modulating prokaryote photodamage and grazing mortality. We suggest that these variations may have important implications for oceanic carbon uptake and export, and could provide strong empirical constraints for large-scale biogeochemical models.

Keywords: ocean, time series, phytoplankton, biomass, BATS

Oral presentation

Monthly maps of sea surface nutrients in the North Pacific: Basin-wide distribution and seasonal to interannual variations

Yasunaka S., Nojiri Y., Ono T., Nakaoka S.-I. and Whitney F.A.

This study produced 120 monthly maps of sea surface nutrient (phosphate, nitrate and silicate) concentrations for the North Pacific from 2001 to 2010 using a self-organizing map of temperature, salinity, chlorophyll-a concentration and mixed layer depth with nutrient observations mainly obtained from commercial ships. Correlation coefficients between the estimation and the observation were greater than 0.8, and root-mean-square differences were $0.14 \mu\text{mol kg}^{-1}$ for phosphate, $1.80 \mu\text{mol kg}^{-1}$ for nitrate and $3.56 \mu\text{mol kg}^{-1}$ for silicate. Seasonal decrease of nutrient concentrations was large in the northwestern part, but the spatial distributions were slightly different among the elements. The stoichiometric ratio of seasonal decreases of silicate and nitrate was larger in western subarctic Pacific and the Bering Sea than in eastern subarctic Pacific, suggesting differing prevalence of diatoms. According to the interannual variation, the Pacific Decadal Oscillation (PDO) was related to the seesaw pattern between the boundary region and the Alaskan Gyre by changes in horizontal advection, vertical mixing and biological production.

Keywords: North Pacific sea surface nutrients

Poster presentation

Session A3: Modelling and data synthesis of marine planktonic ecosystems using functional types and trait-based approaches

Oral Presentations

Tuesday 24 June, 11:00-12:30, Parallel session 1

Room D4

Time	Presenter	Title
11:00-11:15	Vogt, Meike	Present and future phytoplankton biogeography in the global ocean
11:15-11:30	Hashioka, Taketo	Potential responses of phytoplankton community structure to future global warming
11:30-11:45	Thingstad, T. Frede	Coupling of biogeochemical fluxes, biological diversity, and trade off between competitive and defensive traits in microbes
11:45-12:00	Marki, Alexandra	Optimality-based modelling of the effect of nutrient stoichiometry on mesocosm food web succession
12:00-12:15	Mousing, Erik Askov	The effect of small scale spatial heterogeneity on phytoplankton diversity in the North Atlantic Spring bloom
12:15-12:30	Bopp, Laurent	Phytoplankton diversity affected by oceanic dispersal, mesoscale eddies and submesoscale fronts

Tuesday 24 June, 14:00-15:30, Parallel session 2 (A3.2)

Time	Presenter	Title
14:00-14:15	Taucher, Jan	Combining experiments and models to improve representation of plankton functional types and their sensitivity to climate change
14:15-14:30	Lygre, Kjetil	Global plankton data and marine ecosystem modelling - GreenSeas
14:30-14:45	Vallina, Sergio	Global relationship between phytoplankton diversity and productivity in the ocean
14:45-15:00	Giske, Jarl	Oceans of emotions: a new approach to modelling vertical behaviour in mesopelagic fish
15:00-15:15	Schartau, Markus	Towards a systematic statistical evaluation of diverse plankton-/ecosystem models against observations from mesocosm experiments
15:15-15:30	Tyrrell, Toby	Constraints on calcifiers (CaCO ₃ cycling) from a new analysis of global surface ocean alkalinity

Tuesday 24 June, 16:00-17:30, Parallel session 3 (A3.3)

Session A3: Marine planktonic ecosystems

Time	Presenter	Title
16:00-16:15	Menden-Deuer, Susanne	Is variety the spice of life?
16:15-16:30	de Boissieu, Florian	A SVM-based algorithm for global PFT mapping from space
16:30-16:45	Landolfi, Angela	Expanding the ecological niche of marine N ₂ fixers
16:45-17:00	Korosov, Anton	Estimation of onset of the spring phytoplankton blooms in the Nordic Seas from satellite and modeling data
17:00-17:15	Fiksen, Øyvind	Marine ecosystem models with adaptive organisms: when evolution meets biogeochemistry
17:15-17:30	Rabouille, Sophie	Phytoplankton: Exploring cell behaviour to picture and predict larger scale processes

Poster Presentations

Tuesday 24 June, 17:30, Poster Session 1

ID	Presenter	Title
A3.P1	García-Comas, Carmen	Exploring the variability and role of functional diversity on copepod communities of the western subarctic North Pacific
A3.P2	Carlotti, Francois	Detecting habitats considering the mesozooplankton size structure and environmental conditions in the Gulf of Lion, NW Mediterranean Sea
A3.P3	Carlotti, François	Modeling the spatial and temporal population dynamics of the copepod <i>Centropages typicus</i> in the northwestern Mediterranean Sea during the year 2001 using a 3D ecosystem model
A3.P4	Ejsmond, Maciej	Explaining body size and reproduction of the copepods <i>Calanus</i> spp.: predictions from a life history model
A3.P5	Boatman, Toby	The combined effect of Temperature, CO ₂ and Light Intensity on <i>Trichodesmium</i> 's growth
A3.P6	Perez Torres, Asvin	Ontogenetic variations in the vertical distribution patterns of decapod crustaceans, model from meroplanktonic larvae to pelagic adults
A3.P7	Darnis, Gerald	Diel variations in the vertical distribution of arctic mesozooplankton during the polar night
A3.P8	Zhao, Liang	An ecosystem model study on the trajectory of green tides in the Yellow Sea
A3.P9	Khelifi-Touhami, Meriem	Biogeochemical and Plankton Features of Algerian Coastal Environments
A3.P10	Lehodey, Patrick	Predicting cetacean habitats from their energetic needs and the distribution of their prey in two contrasted tropical regions
A3.P11	Nejstgaard, Jens	Behavioral responses of planktonic ciliates to presence of predatory copepods

The combined effect of Temperature, CO₂ and Light Intensity on *Trichodesmium*'s growth

Boatman T., Geider R. and Upton G.

Trichodesmium spp. is a diazotrophic cyanobacteria found in the equatorial regions of all open ocean basins. It significantly contributes to several biogeochemical cycles (i.e. the carbon and nitrogen) both directly through its productivity, and indirectly by providing fixed nitrogen to other phytoplankton.

Over the past decade, there has been considerable incongruity regarding the effect climate change will have on the growth of *Trichodesmium* IMS101. This is important as changes to growth will directly influence their global distribution, and would have major implications on global biogeochemical cycles, food web dynamics, and open ocean productivity.

To address these discrepancies, *Trichodesmium* were cultured in balanced growth using semi-continuous batch culturing techniques at three CO₂ concentrations (180, 380, and 720ppm), two light intensities (40 and 400 μmol m⁻² s⁻¹), and 20 temperatures (ranging between 19 and 31°C) for a period of nine months. Growth rates were determined by daily fluorescence and calculated by changes in dark adapted minimum fluorescence. Each growth curve was analysed with an R code which automated the calculation of growth rate. From this, a median growth rate was calculated for each of the 120 culture treatments.

It was revealed that for both the low and high light cultures, there is a significant increase in growth rates achieved across the entire temperature gradient with increasing CO₂, where the μ_{max} at T_{opt} is 0.18, 0.31 and 0.34 d⁻¹ at 180 380 and 720ppm CO₂ (High Light), respectively. It is also apparent that in addition to altering the μ_{max}, CO₂ concentration also significantly affects both of the temperature extremes (T_{min} and T_{max}) for *Trichodesmium* growth, where a greater CO₂ concentration allows for a lower T_{min} and higher T_{max} temperature.

Supplementary data was collected detailing the effect light intensity has on *Trichodesmium* growth. A novel sine function was formulated to model the temperature response on growth, which was incorporated with light and CO₂ functions. Using oceanographic data estimated for future years, the fundamental niche of *Trichodesmium* IM101 in the Atlantic Ocean basin was modelled to identify how climate change may affect their distribution over the coming decades.

In addition to ocean acidification; climate change will also bring increased SST's. My research shows that growth rates decrease significantly over a 3 to 4°C shift from the optimal (26°C). However, the aerial distribution of *Trichodesmium* spp. may increase as the 20°C isotherm slowly shifts pole-ward. It is still unclear at what point the negative effects of climate change (e.g. increase water stratification, SST's etc) begin to outweigh the positive effects of an increased latitudinal distribution.

Keywords: *Trichodesmium*, temperature, light intensity, CO₂, niche

Poster presentation

Phytoplankton diversity affected by oceanic dispersal, mesoscale eddies and submesoscale fronts

Lévy M., Jahn O., Dutkiewicz S., d'Ovidio F. and Follows M. Presented by Bopp L.

We explore the role of oceanic dispersal in setting patterns of phytoplankton diversity, with emphasis on the role of mesoscale turbulence, in the context of numerical simulations that resolve mesoscale eddies, submesoscale fronts and a diverse set of phytoplankton types whose physiological traits are randomly assigned from ranges defined by field and laboratory data. This flexible representation of community structure is used to explore the role of the physical environment on resource competition. In this model, the community structure and diversity are not imposed, but emerge from a wider set of possibilities. More specifically, we examine how phytoplankton diversity is affected by the physical dispersion induced by ocean currents, over spatial scales ranging from $O(1000)$ km to $O(10)$ km, using a set of numerical simulations where we progressively account for different classes of motion. We found that with the progressive inclusion of mechanisms of dispersal, the population becomes dominated by a smaller number of types but with larger degree of co-existence, in larger home range areas. Co-existence occurs preferentially over sub-mesoscale fronts. In contrast, the number of species able to co-exist decreases with time in the core of retentive eddies.

Keywords: submesoscale permitting darwin model

Oral presentation

Modeling the spatial and temporal population dynamics of the copepod *Centropages typicus* in the northwestern Mediterranean Sea during the year 2001 using a 3D ecosystem model

Carlotti, F., Diaz, F., Eisenhauer, L. and Campbell, R.

The spatio-temporal dynamics of *Centropages typicus* population during the year 2001 in the northwestern Mediterranean Sea are addressed using a 3D coupled physical-biogeochemical model. The setup comprises a plankton ecosystem model and a stage-structured population model forced by the 3D velocity and temperature fields provided by an eddy-resolving regional circulation model. The objective is to characterize *C. typicus* ontogenic habitats driven by physical and trophic processes. The simulated spatial patterns of *C. typicus* stages are closely related to mesoscale hydrodynamic features. The seasonal and spatial distributions on the Gulf of Lions shelf depend on the seasonal interplay between the Rhône river plume, the mesoscale eddies and the Northern Current acting as a dynamic barrier or allowing cross-shelf exchanges. In the central gyre, the plankton patchiness is linked to mesoscale frontal systems, surface eddies and filaments and deep gradients. Due to its flexibility in diet, *C. typicus* succeeds in maintaining its population in both coastal and offshore areas year round. In late fall and winter, the results of the model suggest the existence of three refuge areas where the population maintains winter generations.

Keywords: *Centropages typicus*, North-Western-Med-Sea, seasonal spatial patterns

Poster presentation

Detecting habitats considering the mesozooplankton size structure and environmental conditions in the Gulf of Lion, NW Mediterranean Sea

Espinasse B., Carlotti F., Zhou M. and Devenon J.-L.

The Gulf of Lion in northwestern Mediterranean Sea is characterized by a large continental shelf reaching up 40 miles width. Several hydroclimatic processes such as river discharges, strong winds and permanent current induce a complex hydrodynamics. Such changing conditions create several habitats for plankton communities.

The whole French continental shelf of the Gulf of Lion was sampled at two periods (May 2010 and January 2011) to obtain an overview on the zooplankton community size structure. Six transects from the coast to the open ocean were conducted for a total of 160 stations. A laser optical plankton counter (LOPC) was used to estimate abundance and general characteristics of size spectra. The vertical distribution of the LOPC counts and several environmental parameters were investigated in order to highlight their interactions and the main structures.

A Principal Components Analysis (PCA) was performed on physicals and biological parameters to interpret the links between the different parameters. A clustering test allowed us to define three coherent ecoregions representing different types of habitat: (1) the coastal area, (2) the Rhône plume influence and (3) the continental shelf area. The zooplankton size distribution was investigated within the three areas using the normalized biomass size spectrum (NBSS). The size structure of zooplankton community differs following the areas and their environmental conditions. The coastal area was characterized by the steepest NBSS and highest Chla concentrations, the upwelling and the formation of deep water participated to keep the water mixed. The Rhône plume showed the lowest NBSS slopes associated with strong water stratification. These waters were rich in nutrient promoted high chlorophyll a concentrations in the surface water layer and carried on the continental shelf a lot of organic matter. The continental shelf showed the lowest abundances and was hit by the Northern Current depending on the season.

Keywords: coastal plankton dynamics, size-spectra habitat, Gulf of Lion

Poster presentation

Diel variations in the vertical distribution of arctic mesozooplankton during the polar night

Darnis G., Grenvald J.C., Søreide J., Berge J., Renaud P. and Falk-Petersen S.

Zooplankton Diel Vertical Migration (DVM) occurs in all oceans and lakes, constituting the most widespread and synchronized movement of biomass on the planet. Therefore, DVM should be a crucial factor to consider if we are to understand marine food-web interactions and ecosystem structure. Typically, the migrating species remain at depth during daylight hours and move en masse to the surface under cover of darkness, and the cue for this behaviour is widely accepted to be changes in light intensity. But recent studies in Svalbard provide evidence for synchronized DVM of arctic zooplankton in the polar night period when intensity and diel variation of ambient light are minimal, and very little food is available at the surface. To date, the taxa performing this dark DVM remain unknown, and so are the reasons for such winter activity since the research was essentially based on data collected with acoustic instruments moored in the water column. Within the framework of the Circa (Circadian rhythms of Arctic zooplankton) project, the present study describes the zooplankton composition and vertical distribution of mesozooplankton (0.2 to 20 mm size fraction) in January and February 2012 and 2013 in different Svalbard fjords. We compared midday and midnight abundance profiles to identify the taxa within this size class that may perform DVM. The case of the numerically dominant copepods *Oithona similis*, *Microcalanus* spp., *Calanus* spp. and *Metridia longa* will be discussed in the context of polar night DVM.

Keywords: Arctic zooplankton, DVM, Polar night

Poster presentation

A SVM-based algorithm for global PFT mapping from space

de Boissieu F., Menkes C., Alvain S., Dupouy C., Rodier M., Mangeas M., Bonnet S., Lefèvre J. and Frouin R.

Assessing PFT distribution is essential for modeling carbon and nitrogen fluxes at a global scale. In recent years the availability of satellite-borne multispectral data as well as the accumulation of in-situ data has enabled great progress in global mapping of dominant Phytoplankton Functional Types (PFTs). Two main types of remote sensing methods have emerged for PFT recognition, the pigment-based methods and the abundance-based methods. The pigment-based methods link reflectance anomalies, i.e. reflectance spectra normalized to chlorophyll-a concentration, to PFT accessory pigment specificities. The abundance-based methods, on the other hand, use relations between PFTs, phytoplankton size and chlorophyll-a concentration. Both kinds of methods may be ambiguous for certain PFTs and efficient for others.

In this work, we explore the recognition of several dominant PFTs through a non-linear statistical method, i.e. Support Vector Machine (SVM), enhanced with the probability estimation layer. This algorithm provides the probability of occurrence of each phytoplankton type against the others. At the end of the processing sequence, a threshold is applied to convert probability values into classes. The probability threshold defines the confidence level above which the sample is labeled with the most probable class, and under which it is labeled as “not-classifiable”. The higher the threshold, the fewer the confusions in the classification, but more pixels are declared “not-classifiable”. Thus, this algorithm allows a non-linear separation of the classes in the input space, a probability estimation of the PFTs and a classification of the dominant PFT with a control of the compromise between confidence and spatial cover. Moreover, reflectance anomalies, chlorophyll concentration and other environmental parameters, such as sea surface temperature, are jointly used as input to exploit information about abundance and pigments. Training and validation of the recognition algorithm is made through a k-fold cross-validation procedure applied on a large dataset with coincident in-situ and satellite-based observations in various oceanographic environments.

At first, this classification algorithm is used with a feed-forward selection procedure to evaluate the discrimination power of the input features and their combinations. The features contributing most to the recognition are used to train the classifier and achieve high accuracy and stability. This classifier is applied on daily global datasets extracted from level 3 space-borne data for the period 1998-now (SeaWiFS, MODIS). The results are presented as daily PFT probability maps which are averaged at different time scales and converted to dominant PFT maps. These maps are confronted to existing models, in quantitative and qualitative comparisons, to assess the consistency of this classification. In the future, we plan to expand the training database and increase the diversity of in-situ observations, and to adapt the algorithm to a regionalized recognition. PFT distribution according to marine and atmospheric dynamics will also be explored.

Keywords: Phytoplankton, PFT, classification, SVM, Remote Sensing

Oral presentation

Explaining body size and reproduction of the copepods *Calanus* spp.: predictions from a life history model

Ejsmond M.J., McNamara J.M., Søreide J. and Varpe Ø.

Life history theory predicts that organism schedule activities and allocate time and resources, so that the number of descendants left far in the future is maximized. Because a change in the life cycle at one point drives changes in the rest of life cycle, a life history approach is very valuable for predictions on animal responses to changing phenology of their food or predators. Here we report from an annual routine model focused on the genus *Calanus*, abundant, large and lipid rich marine copepods inhabiting Arctic and sub-Arctic regions. The species *C. finmarchicus*, *C. glacialis* and *C. hyperboreus* differ with respect to size at maturity and degree of capital breeding. The seasonality of their environment, with duration and timing of food availability changing with latitude is one potential explanation for observed life history variability. For instance, the more pronounced the seasonality the less time the animals will have for activities and potentially instead of one year, need two or even three years dedicated to growth and gathering reserves used later for reproduction. Ultimate explanations of the observed life history variability should take into account variability in body size and its interactions with time and mode (capital vs. income breeding) of reproduction. In our life history model we allow individuals to schedule growth, storage and reproduction during the year. The modeled animals also decide about timing of diapause. To obtain the optimal strategy, i.e. the one that maximizes fitness, we use dynamic optimization. The state space of our model is large enough to predict all of the observed *Calanus* spp. strategies, from the smaller and short lived *C. finmarchicus* to the large and long-lived *C. hyperboreus*. We can predict under what conditions each of them are more likely to occur, helping us to understand the geographical distribution of the three species. The model is also a strong general tool for investigation of the trade-off between current and future (residual) reproductive investment represented in our model by three components: reproduction, growth and storage.

Keywords: *Calanus*, phenology, size, capital breeding, life-history

Poster presentation

Marine ecosystem models with adaptive organisms: when evolution meets biogeochemistry

Fiksen Ø. and Castellani M.

Marine ecosystems are regulated both from below (resources and competition) and from above (predation) - while individual organisms are navigating adaptively in the fitness landscape generated by competition and predation, growth and mortality. The structure of an ecosystem is an emergent property of the evolutionary games between the organisms and the constraints placed by chemistry and physics. However, the influence of predators, zooplankton size-structure or of flexible behavioural interactions are rarely considered in ocean models.

We have developed a 1D model of a marine ecosystem with fish, zooplankton and phytoplankton where fish are optimal foragers; they ignore and do not waste valuable handling time on non-profitable prey, and perform active prey choice among available prey. Fish (the fish biomass) move continuously towards depth locations where they increase their food intake. Similarly, mesozooplankton feed on a mixed diet, and we have developed an algorithm where zooplankton biomass within each size class moves towards surrounding habitats with higher net biomass growth rate. This frequently involves a tradeoff between increasing the ingestion of phytoplankton or smaller zooplankton, which tend to be located near the surface, the risk of being eaten by fish, which see better in the higher illumination near the surface, and the risk of being eaten by larger zooplankton, which is more abundant in deeper habitats during the day. The diel cycle in radiation and the vertical gradients in productivity, light, and predators generate a spatial and temporal landscape where a diverse zooplankton community may emerge.

Here, we focus on the construction and properties of such a biologically complex model. We have explored the sensitivity of the model to a wide range of parameters and assumptions. One interesting set of predictions relates to movement rules of fish and zooplankton in the model, and the consequences of these assumptions for ecosystem structure and dynamics. Another challenge is the sensitivity to the formulation of prey preferences or diet selection in situations with multiple prey available. We argue that evolutionary reasoning and algorithms should be applied in these processes, and that a combination of evolutionary and biogeochemical principles are required in modelling marine ecosystems from end to end.

Keywords: marine ecosystem model trait-based adaptive fish

Oral presentation

Exploring the variability and role of functional diversity on copepod communities of the western subarctic North Pacific

García-Comas C., Chiba S., Hashioka T. and Smith S.L.

Understanding the role of biodiversity in ecosystem functioning and the relationship of biodiversity with environment is a major challenge in ecology. Multiple studies have identified positive relationships between species richness and functioning for terrestrial plants. Nevertheless, mechanisms are not yet well understood, particularly in planktonic communities. Recently there has been increasing interest in relating functional-trait diversity to ecosystem functioning, out of concern that species richness may hide high functional redundancy. Studies based on functional traits have revealed new patterns thereby enhancing understanding of community structure and ecosystem functioning. For example, a global scale study of biodiversity of reef fishes has unveiled unexpected latitudinal patterns of functional-trait diversity and evenness of species in contrast to the widely recognized decrease of species richness towards higher latitudes. Still, not much is known about the generality of such patterns of functional diversity nor their implications for the structure and function of ecosystems. In order to further investigate diversity-functioning relationships and susceptibility to environmental forcing, we analyze copepod species observations from the historical ODATE dataset, which consists of 3142 samples covering the period 1960-2002 for a $\sim 10 \times 10^\circ$ area including the Oyashio-Kuroshio Transition System, east of Japan in the western subarctic North Pacific. The dataset consists of a total of 332 species constituting distinctive communities. The 162 most important species in terms of abundance, biomass and commonness, have been classified in terms of five functional traits. First, we explore the spatial and seasonal variability of species richness, species diversity and trait diversity (both expressed as effective numbers), as well as their inter-relationships. Secondly, we analyze their relationships with the copepod bulk biomass as well as the total biomass per unit Chla. Finally, we depict relationships with environmental conditions (e.g., SST, MLD and nutrient concentrations) in order to elucidate anticipated differences in these relationships between distinct water-masses.

Keywords: functional diversity, diversity-ecosystem functioning, redundancy

Poster presentation

Oceans of emotions: a new approach to modelling vertical behaviour in mesopelagic fish

Giske J., Eliassen S., Andersen B.S, Fiksen Ø., Jakobsen P.J., Aksnes D.L., Mangel M. and Jørgensen C.

During the past decade, population modelling has increased in importance as a tool for understanding human impacts on the environment. In most population models, behaviour is poorly represented if at all, simply because there is no easy way to model organisms that shift between being constrained by physiological demands and by the actions of their conspecifics, or are so simultaneously. Ever since ecologists started using mathematical models, animal behaviour has been studied as a means of maximizing evolutionary fitness, through survival and offspring production. However, animals do not perform such calculations. So how can organisms make evolutionarily sensible decisions without calculating the consequences?

We address this in a model of fish behaviour, where all rational calculations of future consequences are replaced by a model of the emotion system. A population of mesopelagic fish with emotions is evolved over a series of generations, where offspring inherit traits related to the emotions, such as how seeing more food increases hunger or how more light increases fear. We show that the emotion system, through focused attention, can prioritize among competing demands, as in natural organisms. We find clear similarities between fish behaviour in the model and classical models of evolutionarily optimal decisions, but we also find some interesting differences, e.g. that populations tend to become divided into distinct personality types.

We also show that multi-layered trait architecture and its associated constraints prescribe diversity. Trait architecture yields genetic and phenotypic diversity even in absence of frequency-dependent selection or environmental variation. That is, repeat simulations show that for a given environment, phenotypes are predictable while gene pools are not. The conservation of phenotypic traits among these genetically different populations is due to multi-layered trait architecture, in which one adaptation at a higher architectural level can be achieved by several different adaptations at a lower level. While trait architecture makes individuals more constrained than what has been assumed in optimization theory, the resulting populations are genetically more diverse and adaptable. This may have consequences for population adaptation to environmental change. The emotion system in animals may thus have evolved by natural selection because it simultaneously enhances three important functions, the behavioural robustness of individuals, the evolvability of gene pools, and the rate of evolutionary innovation at several architectural levels. The first two of these functions are also relevant for marine ecosystem modelling over ecological time scales.

One benefit of this approach is that a consideration of emotions in fish and other organisms takes us one step closer to how animals live and behave. Another is that focus on the

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mechanisms involved in behaviour facilitates dialogue between empiricists and theoreticians and across behavioural disciplines such as genetics, physiology, psychology, neuroscience, and evolution. Finally, it opens the way for more realistic models of variations in behaviour among individuals in natural populations, far beyond mesopelagic fish, to the benefit of researchers in conservation biology and environmental studies.

Keywords: mesopelagic, trait-architecture, emotion-system, population-diversity, animal-personality, behaviour

Oral presentation

Potential responses of phytoplankton community structure to future global warming

Hashioka T., Hirata T., Chiba S. and Yamanaka Y.

In recent studies using high-performance liquid chromatography (HPLC) pigment data, empirical relationships between total chl-a concentration and a phytoplankton size/PFT fraction on a global scale are shown. For example, a fraction of diatoms increases with total chl-a concentration. The same tendencies can be seen in the most of the hindcast experiments by current PFT models of MARine Ecosystem Model Intercomparison Project (MAREMIP) and Coupled Model Intercomparison Project Phase5 (CMIP5) although the reproduced absolute values of a phytoplankton fraction still has large uncertainties. Then, two different mechanisms can be expected as potential responses of phytoplankton community to global warming. One is a possibility that the phytoplankton community structure (i.e., relationships between a phytoplankton fraction and total chl-a concentration) can be significantly changed by changes in ecosystem dynamics under global warming condition (e.g., changes in grazing pass/strength, decomposition/mortality/respiration rate and phytoplankton stoichiometry). Another possibility is that the plankton community shifts to the other stable states associated with changes in total chl-a concentration (e.g., by decrease/increase in nutrient supply to the surface ocean by changes in stratification) while maintaining the current relationship between a phytoplankton fraction and total chl-a concentration. To clarify impacts of both effects, we analyzed model results of future simulation, which was conducted by CMIP5 and MAREMIP under the RCP8.5 emission scenario. PFT model more than half showed that relationships between phytoplankton composition and total chl-a concentration are stable against environmental changes associated with global warming. In these model results, changes in phytoplankton composition are mainly caused by plankton community shifts associated with changes in total chl-a concentration. This result suggests the possibility that current empirical relationships obtained by HPLC would be maintained in a future environment. Based on this hypothesis, we project a potential future community structure of phytoplankton using a multi-model ensemble mean of future changes in total chl-a concentration with the empirical relationship of HPLC. Some other models projected large changes in the community structure in specific regions and seasons. These results also suggest potentially important mechanisms, regions and seasons.

Keywords: Future projection, phytoplankton community structure

Oral presentation

Biogeochemical and plankton features of Algerian coastal environments

Khelifi-Touhami M., Ounissi M., Haridi A. and Laskri H.

To promote understanding of Mediterranean ecosystem changes, studies on land-sea interaction in terms of biogeochemical and plankton changes were carried out from various eastern Algerian aquatic environments (coastal water, lagoon, estuaries). The Bay of Annaba is enriched by two estuaries (Mafragh and Seybouse) input, despite direct domestic and industrial wastes. The Mellah lagoon is a unique Mediterranean dilution basin, connected to the sea by a narrow and stretched channel allowing little exchange with the adjacent sea. The Seybouse and Mafragh Rivers have atypical estuarine parts, with hydrological cycles strongly controlled by marshlands and dams effect. In addition to physical parameters, the data we collected include nutrient concentrations and fluxes from the estuaries and domestic and industrial wastes, and plankton analysis of the Mellah lagoon and the Bay of Annaba. According to the site or the source, nutrient inputs were mostly surveyed for the period 2003-2010. The Mafragh estuary appears to be less impacted in terms of NH_4 and PO_4 , and can play a positive role by introducing clean waters that may mitigate the highly polluted Seybouse inputs. It seems to function as a natural fertilizer against the receiving coast as its concentration in nutrient are somewhat low and the Redfield ratios N:P and Si:N are also balanced. The average values of silicate concentrations are in our estuaries very low, compared to the average value of word Rivers. This lowering does not only derive from geological consideration but also could be related to dam and marshland retentions. In the Bay of Annaba, plankton community is under strong continental influences, where the coastal contingent is abundant but weakly diversified. These influences are spatially limited outside the estuaries plumes. Beyond this area northward, the external water seems to be crucial in controlling the biodiversity and structuring the zooplankton community. The hydrological and tidal cycles of the Mellah lagoon are the major forcing drivers that control the plankton dynamics and biodiversity. The Mellah plankton communities are rather submitted to the continental influences in wet season, but still subject to marine intrusions in dry season.

Keywords: Coastal waters; Nutrients; Plankton; Estuary; Lagoon

Poster presentation

Estimation of onset of the spring phytoplankton blooms in the Nordic Seas from satellite and modeling data

Korosov A. and Pettersson L.

We developed a method for efficient studying of dynamics of environmental variables in 4D space. The method is based on objective zoning of the region of interest and consists in application of the principal component analysis (PCA) and 'k-means' cluster analysis (KMCA) to time series of satellite data.

Our objective was to detect changes in phytoplankton phenology in the Nordic Seas ecosystem using remote sensing and modeling data for last 15 years and to understand which physical factors are influencing the observed interannual alterations in the onset of the spring phytoplankton bloom. We developed an archive of consistent satellite observations (chlorophyll-a, sea surface temperature, photo synthetically available radiation, wind, etc) and hydro-dynamic modeling (mixed layer depth, eddy kinetic energy, etc) in the Nordic Seas and applied the method of objective zoning for analysis of the 4D data (time series of spatial distributions of many parameters).

The method of objective zoning was applied in order to find a limited number of zones (10 – 15) with coherent dynamics of chlorophyll-a in order to average values of the satellite and model based variables within each zone for further joint analysis.

Analysis of all variety of factors that could be identified by means of modeling or remote sensing potentially influencing phytoplankton phenology dynamics showed that it is only the mixed layer depth which changes timing of the bloom. Other factors (e.g. available radiation) influence other bloom characteristics such as duration, or intensity.

Our next step was to analyze time series of data in each identified zone and assess if there are any changes on a decadal time scale. Analysis of spring phytoplankton bloom onset showed that the only significant changes are observed in the North Sea where blooms are now starting earlier (on average by 26 days in 14 years) and in the Barents Sea where blooms are delayed (on average by 9 days in 14 years).

Keywords: phytoplankton bloom, remote sensing, phenology

Oral presentation

Expanding the ecological niche of marine N₂ fixers

Landolfi A., Koeve W., Dietze H. and Oschlies A.

The fixation of N₂ by diazotrophs is essential for the maintenance of the marine fixed nitrogen (N) inventory, regulating marine productivity on centennial timescales. The environmental controls of marine nitrogen fixation are still uncertain and its distribution in the present ocean cannot be fully explained. Slowly growing N₂ fixers are expected to have a competitive advantage where fixed N is in low supply relative to phosphorus (P) with respect to the elemental requirement (R) of non-fixing phytoplankton. To this end the oligotrophic North Atlantic - where the nutrient supply to the surface ocean is elevated in N relative to P but hosts elevated N₂ fixation is particularly enigmatic. Here, we employ a global coupled ecosystem-circulation model to show that accounting for the tradeoffs associated with the costs for the acquisition of phosphorus allows to expand the ecological niche occupied by diazotrophs to regions where the nutrient supply is high in N relative to the elemental requirement of phytoplankton. Our results contribute to reconcile the apparent discrepancy between the supposed niche and the actual occurrence of diazotrophy in the present ocean.

Keywords: N-cycle, marine N₂-fixers, North Atlantic

Oral presentation

Predicting cetacean habitats from their energetic needs and the distribution of their prey in two contrasted tropical regions

Lambert C., Mannocci L., Ridoux V. and Lehodey P.

Most habitat modelling studies relied on static and oceanographic covariates, but very few related cetaceans directly to their prey, often due to the unavailability of such information. We investigated the distribution of 3 cetacean guilds with increasing costs of living (sperm and beaked whales, Globicephalinae, Delphininae) in relation to the biomasses and productions of their prey in 2 tropical regions. We expected energetically costly cetaceans to preferentially forage in habitats of high prey biomasses and/or productions where they can easily meet their high energetic needs, and less active cetaceans to forage in habitats of either high or low prey biomasses and/or productions. Cetacean sightings were collected from dedicated aerial surveys in the Southwest Indian Ocean (SWIO) and French Polynesia (FP). The biomasses and productions of potential preys were simulated by the SEAPODYM model. We examined cetacean densities in relation to the distribution of their prey through Generalized Additive Models and predicted their habitats in both regions. Results supported their known diving abilities. Explained deviances ranged from 9 to 13% for sperm and beaked whales, from 18 to 47% for Globicephalinae, and from 19 to 22% for Delphininae. The costly Delphininae and Globicephalinae appeared to select areas where high prey biomasses and/or productions were available at shallow depth. At the regional scale, models predicted higher densities in the productive SWIO (2.66 individuals/km² for Delphininae, 1.29 for Globicephalinae) compared to the oligotrophic FP (0.10 individuals/km² for Delphininae, 0.07 for Globicephalinae). In contrast, the less active sperm and beaked whales showed no clear habitat selection (0.04 individuals/km² in both regions), indicating that they may sustain their needs by exploiting both productive and oligotrophic areas. This study illustrates that the use of simulated prey distribution in cetacean habitat models is valuable for understanding their strategies of habitat utilisation in both horizontal and vertical dimensions.

Keywords: cetaceans, prey distribution, micronekton, SEAPODYM

Poster presentation

Global plankton data and marine ecosystem modelling – GreenSeas

Lygre K., Bruun J., Allen I., Vichi M., Hamre T., Vines, A., Somerfield P., Samuelsen A., Racault M.-F., Waldron H., Monteiro P., McKiver W., Bellerby R., Thomalla S., Philbert R., Moiseev D., Johannessen J., Brewin R., Butenschön M., Jeansson E. Heard J., Hartmann M. and Garcia C.

By acknowledging the need for an integrated, interdisciplinary approach to address the challenges of global change, the FP7 GreenSeas project has aimed at developing of a global plankton data base, delivery and model system for eco-climate early warning. Phytoplankton is a key component of the marine ecosystem, forming the base of the oceanic food chain, on which larger invertebrates, fish, and mammals depend for their survival. One of the great challenges we are facing is the need to understand and predict the consequences of changes in, inter-alia, climate, biogeochemical cycles and human resource use, and mitigate the impacts, which can only be explored by an integrated, interdisciplinary approach. For the user community - consisting of environmental managers, scientists of various disciplines and others - the amount of available data from historical and upcoming in situ sensor networks and satellite missions, provides a rich opportunity e.g. to derive key environmental and climatic indicators and generate future projections of them by the aid of numerical models.

However, the problem of making different data interoperable and intercomparable remains, due to, among others, differences in terminology and format used by different data providers and the different granularity provided by e.g. in situ data and ocean models.

An objective has therefore been to improve the technology for accessing diverse plankton and associated environmental data sets, along with earth observation data and simulation outputs, in order for the user to extract the adequate set of information in order to address the above questions. To this end, we have developed a web portal enabling users to easily search for in situ or satellite data overlapping in space and time, and compare the retrieved data with e.g. model results. The in situ data are retrieved from a geo-spatial repository containing historical and new physical, biological and chemical parameters currently for the Atlantic Ocean, from the Southern Ocean through the Arctic. The satellite-derived quantities are retrieved from another geo-spatial repository. Both repositories are accessed through standard interfaces, using the Open Geospatial Consortium (OGC) Web Map Service (WMS) and Web Feature Service (WFS), and OPeNDAP protocols, respectively.

To navigate the huge number of plankton parameters, plankton is grouped according to category, size and (if available) by element, also reflected in the graphical user interface, showing a tree structure, enabling the user to quickly get an overview of available data, and choosing a suitable level of detail. Once decided, the system will retrieve available parameters. The user can also compare data products, shown as plots (e.g. scatter plots), through simple statistical measures or near-coincident values and may be exported for further analysis. With this first generation data delivery system we have demonstrated that a customized tool for searching, presenting and exporting ocean data from multiple platforms (in situ, satellite, model), makes it easy to compare various sets of independent observations and model simulations. This method will be subsequently developed in future research, to benefit the wider community of ocean scientists and managers.

Keywords: plankton food-chain interdisciplinary science management projections

Oral presentation

Optimality-based modelling of the effect of nutrient stoichiometry on mesocosm food web succession

Marki A. and Pahlow M.

Recent mesocosm experiments have greatly advanced our ability to observe and to follow the development of natural plankton communities over a period of time.

Here we combine optimality-based models of variable phytoplankton stoichiometry and zooplankton foraging to construct a simple food web with one to three trophic levels to analyse plankton processes in mesocosms. We analyse observations from shipboard mesocosm experiments with the help of several model configurations. The NP model configuration consists of the nutrient and phytoplankton compartments only, and is used to calibrate the phytoplankton parameters to match the onset of the mesocosm phytoplankton development. We add one or two zooplankton compartments with pre-calibrated parametersets in the other configurations. The NPH model configuration contains one herbivorous zooplankton compartment. Only ciliate and dinoflagellate parameters result in an acceptable agreement between the NPH model and the observations, which is encouraging as copepods were not present in the mesocosms. We find that the initial predator concentration has a strong effect on short term remineralisation processes. Nevertheless, the NPH configuration tends to overestimate phytoplankton and underestimate nutrients towards the end of the experiments. The NPHC configuration has a second, carnivorous zooplankton compartment, preying on the herbivore introduced in the NPH configuration. The carnivore behaviour is described with ciliate parameters, whereas the herbivore is represented by a dinoflagellate and all organisms are defined as food specialists. Most zooplankton species in the ocean are omnivorous and therefore we extend the feeding behaviour of the zooplankton by integrating phytoplankton in the diet, to obtain the NPHCv configuration. This first attempt towards omnivory results in an overall slightly better nutrient and biomass representation. Accordingly, we implement omnivory for all zooplankton species in the NPHCo configuration, including trophic level-up, trophic level-down and intra-guild predation. The NPHCo configuration gives the most realistic remineralisation compared to the observations. We conclude that at least three trophic levels, phytoplankton, small omnivores, and big omnivores, are required in the model in order to reproduce the observed behaviour of these mesocosm experiments and propose that the major remineralisation- and higher trophic level-processes are due to omnivorous ciliates. Furthermore our model results suggest and probably point towards strong intra-group differences in nutrient requirements among the zooplankton species.

Keywords: Optimality-based modelling, mesocosms, food-web, nutrient-stoichiometry,

Oral presentation

Is variety the spice of life?

Menden-Deuer S. and Rowlett J.

In apparent contradiction to competition theory, the number of co-existing plankton species far exceeds their explicable biodiversity - a discrepancy termed the Paradox of the Plankton. We introduce a new game-theoretic model for competing micro-organisms that incorporates important characteristics of plankton: vast, clonal populations sizes and considerable degrees of intraspecific variability. Survival and ultimately biodiversity, was evaluated using individual-based, spatially explicit model simulations that match individuals with species-specific, but variable competitive abilities. We find that intra-specific variability is the key characteristic that ultimately allows co-existence of many dozens of species because the outcome of competitions between individuals with variable competitive abilities is unpredictable. Our simulations based on the theoretical model show that up to 100 species can coexist for up to 10000 generations, and that even small population sizes or species with inferior competitive ability can persist when there is intra-specific variability. In nature, this variability can be observed as niche differentiation, variability in environmental and ecological factors, and variability of individual behaviors or physiology. Previous explanations of the paradox are consistent with and provide specific examples of our suggestion that individual variability is the mechanism that results in the apparent conundrum of a highly diverse planktonic community in an apparently uniform ocean. As a consequence characterization of intra-specific variability will be particularly important in assessing species ability to withstand changing environmental conditions

Keywords: plankton, variability, biodiversity, coexistence

Oral presentation

The effect of small scale spatial heterogeneity on phytoplankton diversity in the North Atlantic Spring bloom

Mousing E.A., Richardson K., Bendtsen J., Cetinić I. and Perry M.J.

Phytoplankton community composition in 30 samples from the Northeastern Atlantic during the onset of the spring bloom in 2008 was examined in an effort to identify and understand the effect of small scale spatial heterogeneity on phytoplankton community composition and diversity. Species assemblages divided into two groups each associated with specific salinity characteristics. These characteristics corresponded almost exactly with the patches formed by eddy-driven stratification identified by Mahadevan et al. (2012). Patch regions were dominated by species from the genus *Chaetoceros* and the samples collected here were characterized by having high biomass and taxonomic richness compared to the surrounding water (outside patch regions). Furthermore, both time and temperature were identified as important predictors of beta diversity in patch regions suggesting that community development was evolving from a similar start population and that increasing temperature could be an important driver of change in community composition. The surrounding water (outside patch regions), were dominated by the species *Cerataulina pelagica* and the samples were characterized by having low biomass as well as taxonomic richness. Beta diversity outside patch regions showed a weak correlation with salinity indicating that similar waters masses had slightly similar taxonomic compositions. The lack of strong correlations with any of the measures abiotic variables outside patch regions, however, suggest that community composition in these regions were primarily controlled by stochastic processes. Overall, this study indicates that small scale spatial heterogeneity can impact regional scale phytoplankton diversity patterns.

Mahadevan A, D'Asaro E, Lee C, Perry MJ (2012) Eddy-driven stratification initiates North Atlantic spring phytoplankton blooms. *Science* 337: 54-58.

Keywords: Phytoplankton, Spatial heterogeneity, Richness, Beta-diversity, Spring-bloom

Oral presentation

Behavioral responses of planktonic ciliates to presence of predatory copepods.

Nejstgaard, J.C., Arora V., Berger S.A., Birsa L.M., Jakobsen H.H.

As consumers of protist plankton, planktonic ciliates provide important pathways for energy in marine and freshwater microbial food webs. While direct mortality of ciliates by predation is considered in food web models, less is known about the impact of non-predation processes (e.g. escape behavior) on the trophic transfer efficiency by ciliates. Ciliates limit their predation mortality by escaping zooplankton predators. However, since most ciliates use the same sets of cilia for both propulsion and prey capture, we propose that ciliate feeding is limited during escape, and that the increased velocity and jump frequency during escape impose further energy losses to the ciliate. We propose that the escape behavior is a costly process that significantly limits the overall ciliate growth and survival, and therefore trophic transfer that needs to be factored into plankton food web models. We present results from video studies of ciliate behavior and feeding studies of different marine planktonic ciliate species to test if increased escape behavior (jump frequency and/or swimming velocity) in the presence of predatory copepods (*Acartia tonsa*) significantly impacts the overall ciliate energy budget.

Keywords: Copepods, Ciliates, Trophic transfer, Particle tracking

Poster presentation

Ontogenetic variations in the vertical distribution patterns of decapod crustaceans, model from meroplanktonic larvae to pelagic adults

Perez Torres A., Dos Santos A., Balbína R., Abelló P., Hidalgo M., Alemany F., Massutía E., Regleroa P.

The meroplankton consumes phytoplankton and smaller zooplankton, and in its turn is preyed by larger plankton or pelagic nekton. Thus, its biomass, community structure and spatial distribution will be partly the result of a trade-off between growth and predation through different habitats. Considering that, in general, the Mediterranean Sea is very oligotrophic, we hypothesized that meroplankton vertical distribution, specifically which of crustacean decapods larvae, would be oriented to optimize food availability. The ontogenetic variations in the vertical distribution patterns of decapod are little known, especially for the oceanic species for which research is still very limited. Thus, to test this hypothesis, mesozooplankton and pelagic micronekton sampling was carried out in the Balearic Sea (NW Mediterranean), in late autumn 2009 and summer 2010, using depth-stratified sampling devices. We compared the vertical distribution of successive life cycle stages across species with different adult habitats and life history strategies in these two contrasting scenarios: stratified (summer) and non-stratified (late-autumn) water column. Differences among decapod larvae communities, in terms of composition, adult's habitat such as pelagic or benthic, and distribution patterns were observed between seasons. Most abundant species were larvae of pelagic prawns. The relationships among larval vertical distributions by species and stages and environmental parameters such as fluorescence, salinity and temperature were modeled through GLMs. Our results show migratory behavior of the earliest stages to the euphotic zone despite being hatch deep in the water column. The earliest stages of decapod larvae that feed on phytoplankton and detritus preferred to stay closer to the deep maximum of chlorophyll whereas in later stages this behavior was not so marked. In addition, the vertical movements along the whole day cycle, of the different ontogenetic stages of four pelagic decapods species, from larval to adult stages, have been also investigated by means of GLMs, showing that the amplitude of the vertical displacements increases with the age. The results are discussed in terms of survival strategies in oligotrophic environments and trade-offs between larval food availability and survival during ontogeny.

Keywords: Decapod larval developmental stage, vertical migration

Poster presentation

Phytoplankton: Exploring cell behaviour to picture and predict larger scale processes

Rabouille S., Bernard O., Talec A., Pruvost E. and Sciandra A.

Phytoplankton is sensitive to fluctuations in its immediate environment; its reactivity to such small temporal scales first affects the kinetics of elementary processes, then diel physiological, and finally determines its dynamics at the scale of cell growth. Seasonal dynamics in the phytoplankton therefore result from the coupling of longer time scale processes with elementary growth processes such as photosynthesis. Such cascades of complexity scales remain an open issue in ecosystem modelling, as biogeochemical models cannot resolve processes at scales relevant to the plankton.

We developed a microalgae culture setup monitored by computers allowing application of physico-chemical forcing conditions that are more realistic at the cell scale. The dynamical forcings (light, temperature, nutrients) that can be recreated in such device can be driven by numerical outputs from hydrodynamical models. Thus, we can locally recreate the biochemical environment of a phytoplankton cell and its dynamical evolution along time, mimicking processes that can take place in the natural environment.

The set of sampling automaton provides a high frequency monitoring of physiological properties. It thus generates precious data sets on transient dynamics in the plankton, which prove particularly suitable to calibrate and validate mathematical models of inorganic carbon and nitrogen accumulation.

Such joint, theoretical and experimental approaches are currently developed in the framework of fundamental as well as more applied research projects related to biotechnology. Although artificial systems, such as ponds or raceways, prove very different from their natural counterparts, the fundamental questions related to their optimization relevantly echo the comprehension of natural systems. This discussion will be illustrated using specific examples from different frameworks.

Keywords: physico-chemical-forcing, cultures, high-frequency monitoring, model validation

Oral presentation

Towards a systematic statistical evaluation of diverse plankton/ecosystem models against observations from mesocosm experiments

Schartau M.

In ecological and biogeochemical modelling the optimization of model parameter values as well as sensitivity analyses of simulation results with respect to parameter variations are often regarded as bothersome side aspects. It has been argued that these side works are makeshifts to compensate for limitations in our mechanistic understanding of plankton dynamics. Mechanistic descriptions of complex plankton interaction and/or of physiological acclimation are therefore prominent. In this regard improvements can be achieved by introducing physiological and ecological traits to plankton/ecosystem models. These trait-based models are beneficial, since they can downsize the number of empirical parameterizations. They remediate uncertainties in assigning parameter values e.g. to different plankton functional types. But, trait-based models with advanced descriptions of plankton interaction and growth can still hold limitations elsewhere, e.g. when reproducing changes in carbon (C), nitrogen (N), and phosphorus (P) standing stock observations.

In our study we wish to disclose benefits and limitations of some recent approaches to marine plankton modeling, while focusing on variations in C-, N- and P mass flux. We concentrate on three types of plankton models that differ in complicity on microscale but are of similar complexity on system scale. For our analysis we consider a) a simple empirical quota-regulated growth model, b) a model in which growth is determined by optimally adapted traits, and c) a rather complicated growth model with adaptive traits. We investigate to which extent better representations of ecophysiological details can also improve mass flux estimates within a marine ecosystem. As a start we established a working environment in R for models that are incorporated in the Framework for Aquatic Biogeochemical Models (FABM, Bruggeman and Bolding, 2011, EU-FP7 MEECE report). The models are evaluated against data from a series of independent mesocosm studies. Some emphasis will be put on model cross-validation between different mesocosm experiments. In our presentation we provide information about first technical and scientific achievements during the early phase of our small project. Ultimately, we also hope to encourage other scientists (who are interested in statistical assessments of plankton models) to join and contribute to this ongoing research activity.

Keywords: Model assessment, Mesocosm data, Trait-based modelling

Oral presentation

Combining experiments and models to improve representation of plankton functional types and their sensitivity to climate change

Taucher J., Bach L.T., Oschlies A. and Riebesell U.

Many common marine ecosystem models applied on a global scale are not capable of correctly simulating physiological effects at the organism level, associated interactions and effects at the ecosystem level and ultimately the complex processes, such as community changes, which are expected in response to climate change and ocean acidification. Here we present an integrated approach of experimental work and numerical modelling that could help to improve the representation of various functional groups of phytoplankton in marine ecosystem models.

- **Diatoms:** The sensitivity of diatoms to CO₂ and temperature was explored in several experiments. A particular focus was carbon overconsumption after nitrogen depletion and associated release of dissolved inorganic carbon (DOC) and formation of transparent exopolymer particles (TEP), which play a key role in the formation of fast-sinking marine aggregates. Based on these experiments, a model has been developed that is capable of simulating these important processes and their sensitivity to ocean acidification and warming.
- **Coccolithophores:** A series of experiments dissected the effects of CO₂ and pH on growth, photosynthesis and calcification of several coccolithophores. From these results, a conceptual substrate-inhibitor model was derived that allows for extrapolation to larger spatial scales and thus an improved representation of this functional group's sensitivity to on-going ocean acidification in global ecosystem models.
- **Picophytoplankton:** Several offshore mesocosm experiments in different oceanic regions revealed that this group of phytoplankton strongly benefits from ocean acidification. Meta-analysis of experimental datasets and simultaneous model development are conducted to identify the mechanisms behind these observations. The developed model will then be applied to available mesocosm datasets for model validation and improve our understanding of plankton community changes in response to environmental change.

The findings from these various experimental studies and sub-models for the different groups of phytoplankton will then be integrated into a plankton functional type (PFT) model. Ultimately, such an approach with a close coupling of experimental data acquisition and model development will help to improve the representation of different groups of phytoplankton in, as well as their respective sensitivities to environmental change in PFT models.

Keywords: Biogeochemistry, phytoplankton, experiments, modelling, climate change

Oral presentation

Coupling of biogeochemical fluxes, biological diversity, and tradeoff between competitive and defensive traits in microbes.

Thingstad T.F., Våge S., Giske J., Storesund J. and Sandaa R.A.

Viral lysis deflects material from the “upwards” flow in the pelagic food chain, returning it “down” to dissolved material and detritus. Mechanisms partitioning phytoplankton and bacterial production between grazing and viral lysis will therefore strongly affect the balance between new and regenerated production in biogeochemical models. Lytic viruses are also believed to generate diversity within microbial populations. The combination of these two effects thus couples biodiversity to biogeochemistry in a manner different from the traditional biogeochemical roles of various plankton functional types. Models accounting for this role of viruses have existed for more than a decade, but suffer from the problem that they operate with abstract “host groups”. Many defense mechanisms used by microorganisms work to create strains, and “host groups” should therefore be associated with strains rather than with species. The result is an explicit control of abundance at the strain (by viruses) and community (by e.g. grazing or resources) levels, but not at the intermediate level of species. Comparison between models and molecular data based on e.g. 16/18S rDNA then easily becomes confusing. Abundance within a species emerges in this case as the sum over virus-controlled strains. We show how number of strains is determined by a species’ competitive traits, while abundance within strains is determined by its defensive traits. Both sets of traits thus contribute to abundance at the species level and a species’ abundance depends on the trade-off between the two sets of traits. The analysis is relevant to the ongoing debate of which traits makes SAR11 the (probably) most abundant organism in the ocean. It also suggests that the observed dominance of low-active prokaryotes may reflect the price paid for extensive defense, rather than a lack of access to suitable substrates for rapid growth.

Keywords: diversity, viruses, SAR11, dormancy

Oral presentation

Constraints on calcifiers (CaCO₃ cycling) from a new analysis of global surface ocean alkalinity

Tyrrell T., Fry C., Hain M. and Bates N.

Fluxes of calcium carbonate (CaCO₃) form an essential component of the marine carbon cycle and may also affect organic carbon fluxes through ballasting. Alkalinity is a potential tracer of CaCO₃ cycling (calcification, export, dissolution) and thereby of coccolithophore activity. We present results from a synthesis study of a global dataset comprising GLODAP1, CARINA and PACIFICA (GLODAP2 by the time of the conference), in which we looked at surface ocean bottle data from this combined dataset, analysing the distribution of total alkalinity (TA) in the surface ocean and controls over that distribution.

Our analysis appears to have been successful in terms of isolating and subtracting the influences of other processes in order to leave behind a residual dominated by CaCO₃ cycling and also physical processes that introduce alkalinity from deep water. We removed the effects of evaporation and precipitation through salinity normalisation, and the effects of phytoplankton growth and remineralisation (e.g. nitrate uptake and release) using nitrate data. Finally we identified several locations where anomalous (high alkalinity) river inputs were important and corrected for their effects.

Although none of these individual analysis techniques is novel, this is the first time that a global dataset of surface ocean alkalinity has been analysed in this way. In contrast to unmodified alkalinity, which shows little in the way of obvious global trends or patterns, our analysis reveals the existence of coherent and explicable large-amplitude patterns in the residual alkalinity. Low values (~2300 μmol kg⁻¹) of the residual are found throughout the low latitudes including the gyres. In contrast, alkalinity is much higher in the Southern Ocean (by ~110 μmol kg⁻¹) and in the high latitude North Pacific (by ~85 μmol kg⁻¹), but does not increase greatly with latitude in the North Atlantic. We show that the pattern in the residual surface alkalinity agrees with what one would expect for a tracer of coccolithophore activity (similarities to aspects of the nitrate distribution) and one that is returned to the water column at depth rather than near to the surface (similarities to aspects of the silicate distribution). This method of analysis holds promise for constraining the magnitude and spatial location of CaCO₃ export from the surface ocean, and is likely to be useful for modellers in order to validate their representations of coccolithophores (CaCO₃ cycling) and physics.

Keywords: alkalinity, coccolithophores, CaCO₃ cycling, GLODAP2

Oral presentation

Global relationship between phytoplankton diversity and productivity in the ocean

Vallina S. M., Follows M.J., Dutkiewicz S., Montoya J.M., Cermeno P. and Loreau M.

The shape of the productivity-diversity relationship (PDR) for marine phytoplankton has been suggested to be unimodal, i.e. diversity peaking at intermediate levels of productivity. However there are few observations and there has been little attempt to understand the mechanisms that would lead to such a shape for planktonic organisms. Here we use a marine ecosystem model together with community assembly theory to explain the shape of the unimodal PDR we obtain at the global scale. The positive slope from low to intermediate productivity is due to grazer control with selective feeding, which leads to the predator-mediated coexistence of prey. The negative slope at high productivity is due to seasonal blooms of opportunist species that occur before they are regulated by grazers. The negative side is only unveiled when the temporal scale of the observation captures the transient dynamics, which are especially relevant at highly seasonal latitudes. Thus selective predation explains the positive side while transient competitive exclusion explains the negative side of the unimodal PDR curve. The phytoplankton community composition of the positive and negative sides is mostly dominated by slow-growing nutrient specialists and fast-growing nutrient opportunist species, respectively.

Keywords: Productivity, diversity, species competition, selective predation

Oral presentation

Present and future phytoplankton biogeography in the global ocean

Vogt M., Brun P., Psomas A., Zimmermann N., O'Brien C., Swan C., Buitenhuis E., Leblanc K. and Luo Y.

Marine planktonic ecosystems have been observed to change at an unprecedented rate due to climate change, yet the consequences of changes in plankton biogeography for global biogeochemical cycles and higher trophic levels are poorly understood. We use species distribution modeling to simulate global plankton biogeography for species associated with 5 phytoplankton functional types collected as part of the MAREDAT initiative (coccolithophores, diatoms, picophytoplankton, diazotrophs, and Phaeocystis). Monthly habitat suitability patterns are derived based on in situ observations and observed annual and monthly mean levels of physiologically relevant variables such as temperature, nutrient concentrations, mixed layer depth or solar radiation does. Habitats are validated against HPLC pigment distributions and estimates from remote sensing, and the main drivers of the patterns are identified. Phytoplankton habitats are highly dynamic in space and time and show a strong seasonal variability. Diatoms consist of many species with a fairly global distribution. Coccolithophore species can be divided in high latitude blooming, and low latitude non-blooming species. Phaeocystis consists of species with strongly regional distributions that are well predicted by the models in terms of light and temperature conditions. Habitats are then projected forward in time using CMIP5 simulation results for the RCP8.5 emission scenario. In general, a northward expansion of tropical species can be observed. While individual species show significant changes in habitat extent and location, other species with a more global distribution remain unperturbed. The results give a first indication how present and future plankton habitats may look like, and could contribute to the validation of trait- and PFT-based marine ecosystem models.

Keywords: phytoplankton, biogeography, habitat modelling, future projections

Oral presentation

An ecosystem model study on the trajectory of green tides in the Yellow Sea

Zhao L., Sun Q. and Fang J.

There has been an outbreak of green tide blooms every summer in the Yellow Sea since 2008, that has had a great impact on the local environment and ecosystem. The trajectory of the green tides in the Yellow Sea was calculated by using a Lagrangian model, which has been driven by the currents from the Princeton Ocean Model (POM) and the sea surface wind from CCMP. Then an ecosystem model including the production and mortality processes of the green tides was coupled into the trajectory model. The effects of water temperature and short wave radiation on the production and mortality of the green tides were considered in this coupled model. The model results were compared with the inverted distributions of green tides from the satellite data in 2009. Afterward, the influence of the current, sea surface wind and the initial positions of the particles in spring on the distributions of the green tides were discussed. The results suggest that the green tides are mainly originated from the Subei coast, especially in the area of 121°-122°E, 32°-32.5°N. The abundant biomass areas of the green tides tend to move in line with the prevailing wind direction. There is a rapid and continuous increase in the biomass of green tides in May and reach its peak in June. In July, the green tides enter the depletion period of the biomass and disappear in August. The characteristics of the life cycle of green tides could be captured well by this model.

Keywords: Green tides, Trajectory model, Ecosystem model

Poster presentation

Session A4: End-to-end modelling for research and management

Oral presentations

Wednesday 25 June, 11:00-12:30 Parallel session 4

Chair: Stuart Corney

Room D4

Time	Presenter	Title
11:00-11:05	Corney, Stuart	Introduction
11:05-11:25	Maury, Olivier	APECOSM, an Ocean General Ecosystem Model (OGEM) to study marine ecosystems from local to global scales. Application to the study of active and passive transport influence on global marine ecosystem dynamics
11:25-11:40	Fiechter, Jerome	An end-to-end ecosystem model framework to study environmental controls on population dynamics and habitat utilization of forage fish and apex predators in the California Current.
11:40-11:55	Bedford, Merel	A cartoon model for the Kerguelen Axis: modelling variable ice-states and predator-prey interactions
11:55-12:10	Miñarro Villanueva, Sara	An integrated individual-based model as a tool for socio-ecological management of coral reefs in Indonesia
12:10-12:20	Melbourne-Thomas, Jessica	Introduction to SOKI: collaboration tools for end-to-end ecosystem models
12:20 -12:30		Poster presentations (3 minutes each)

Session A4: End-to-end Modelling

14:00-15:30 Parallel session 5

Chair: Jessica Melbourne-Thomas

Room D4

Time	Presenter	Title
14:00-14:15	Kearney, Kelly	Can volcanic-induced primary production explain high salmon returns?
14:15-14:30	Fulton, Beth	Did you realize that humans are animals too?
14:30-14:45	Hansen, Cecilie	Challenges when adapting an end-to-end model to high latitudes
14:45-15:00	Thorpe, Sally	Modelling the early life cycle of Antarctic krill: circumpolar success and sensitivity
15:00-15:15	Politikos, Dimitrios	Understanding anchovy migration cycle of in the Bay of Biscay through individual-based fish movement models
15:15-15:30	Corney, Stuart, Melbourne-Thomas, Jessica and Constable, Andrew	Synthesis and the way forward

Poster Presentations

Wednesday 25 June, 17:30, Poster Session 2

ID	Presenter	Title
A4.P1	Xia, Meng	The development of an unstructured based bio-physical model to Lake Erie yellow perch recruitment
A4.P2	Ardelan, Murat V.	Ocean Food web Patrol - Climate Effects: Reducing Targeted Uncertainties with an Integrated Network (OCEAN-CERTAIN)

Ocean Food web Patrol – Climate Effects: Reducing Targeted Uncertainties with an Integrated Network (OCEAN-CERTAIN)

Ardelan M.V., Sommer U., Thorpe R.B., Bailey J., Thingstad T.F., de Kok, J-L., Bizsel. K.C., Öztürk P., Marsi E., Bratbak G., Turner D., Hoffmann L., Besiktepe S., Chiggiato J., González H.E., Iriarte J.L, Vadstein O, Tiller R., Richards R.G., Salgado H., Engelen G. and Olsen Y.

The marine food web is at the centre of both the climate-related CO₂ cycle and food production in the marine environment. It plays a key role in regulating the climate system and is highly sensitive to climate change and other stressors.

OCEAN-CERTAIN will investigate the impact of climatic and non climatic stressors on the food web (FW) and the associated biological pump (BP), and the important natural and socio-economic feedback mechanisms. OCEAN-CERTAIN will identify and quantify multi-stressor impacts and feedbacks and study how these alter the functionality and structure of the food web and efficiency of the biological pump in different bio-geographical regions, the Arctic, Patagonia and Mediterranean.

OCEAN-CERTAIN aims to reduce targeted uncertainties regarding the effects of climatic and non-climatic stressors on the structure and function of the marine FW and the associated BP. This will be achieved through an integrated effort from the natural, social and computer science domains, drawing upon the tools and methods of data mining, ecosystem modelling, mesocosm and laboratory experiments, field studies, artificial intelligence (in particular, literature-based knowledge discovery) stakeholder-oriented participatory modelling and game theory analysis. This integrated scientific effort will increase the basic knowledge on the feedback structure of the system, including human behaviour and management alternatives. The results will be used to design and test a user-friendly decision-support system to facilitate the communication between marine scientists, stakeholders and managers. The improved understanding of the system feedback behaviour is expected to add to the resilience and adaptability for climate change.

Keywords: food-web, biological-pump, multi-stressor, climate

Poster presentation

A cartoon model for the Kerguelen Axis: modelling variable ice-states and predator-prey interactions

Bedford M., Fulton E., Melbourne-Thomas J., Corney S. and Constable A.

So-called “cartoon” models provide a useful means to test representations and parameterisations of complex ecosystem components, which can then be implemented in larger modelling frameworks including biogeochemical and higher order foodwebs (end-to-end models). We have developed a cartoon model for a representative Antarctic marine ecosystem, specifically for the Kerguelen Axis region in the Indian Sector of the Southern Ocean, using the open-source agent-based modelling framework NetLogo. This model is designed to be a test domain for an implementation of the Atlantis model for a broader region of the Indian Sector.

There have only been limited attempts, to date, to model the full Antarctic ecosystem – including lower and higher trophic levels – and key habitat drivers. Our model incorporates the physical and dynamic status of the Kerguelen Axis, through light calculations based on local latitude and longitude; ice-states; mixed layer depths and sea-ice processes (habitat and primary productivity). All trophic levels (phytoplankton to top predators) are represented in the model, where we have used patch-variables for phytoplankton; matrices for the foraging species (krill and fish); and individual-based representations for predator species (penguins, seals and whales). The model also allows for depletion of fish and krill through fishing activities.

We present results from a set of simple scenarios for change in seasonal sea-ice habitats, in particular changes in ice extent and the timing of sea ice advance and retreat. We also evaluate some of the lessons learnt in representing diverse Southern Ocean taxa in a cartoon model framework, including implications for full representations and parameterisations in larger end-to-end models.

Keywords: Cartoon ecosystem model, Antarctic predator-prey interactions

Oral presentation

Challenges when adapting an end-to-end model to high latitudes

Hansen C. and Mauritzen M.-S.

The end-to-end model Atlantis has been set up for the Nordic and Barents Seas, covering an area of totally 4 million km². The model has been under extensive tuning, as it is the first time it has been adapted to such high latitudes. To represent the ecosystem in the area, 52 functional groups and species have been parameterized, covering all trophic levels from bacteria, phytoplankton, zooplankton and fish to marine mammals. Through the tuning process, there has been made a lot of “guesstimates” and approximations. We will present the vulnerability of the model to some of these, such as mortality rates, feeding rates and growth rates. The difference between making guesstimates on growth and mortality rates in comparison with feeding interactions will be presented for a few chosen species. In addition to direct effects, the indirect effects due to feeding interactions will be explored. Through the study we will identify important areas where more information and research is needed, with focus on both commercially important species, but also on vulnerable species.

Keywords: Atlantis, tuning, Nordic Seas, Barents Sea

Oral presentation

An end-to-end ecosystem model framework to study environmental controls on population dynamics and habitat utilization of forage fish and apex predators in the California Current.

Fiechter J., Huckstadt L., Costa D., Rose K., Curchitser E., Hedstrom K., Edwards C., Moore A.

We present results from a fully coupled end-to-end ecosystem model for the California Current Large Marine Ecosystem (CCLME), with the aim of quantifying the impact of environmental variability on trophic interactions, habitat utilization, and foraging patterns/success of mid- and higher trophic level species. The ecosystem modeling framework consists of a lower trophic level ecosystem model (NEMURO) embedded in a regional ocean circulation model (ROMS), and both coupled with a multi-species individual-based model (IBM) for forage fish (sardine and anchovy) and an apex predator (California sea lion). For sardines and anchovies, population dynamics is based on growth, reproduction, and mortality (natural, predation, and fishing). For sea lions, bioenergetics and behavioral attributes are specified using available TOPP (Tagging Of Pacific Predators) data on their foraging patterns and diet in the CCLME. Output from a 50-year run (1959-2008) of the model shows how different environmental processes (e.g., temperature, prey availability) control sardine and anchovy population dynamics on interannual and decadal timescales, and lead to clear low frequency out-of-phase responses between the two species. We also illustrate how the variability in forage fish distribution and abundance translates to shifts in foraging patterns and success for California sea lions. While specifically focusing on trophic interactions affecting habitat utilization of sea lions in the CCLME, an overarching goal of our end-to-end modeling approach is to better understand and characterize biological “hotspots” (i.e., the aggregation of multiple marine organisms over multiple trophic levels) off the U.S. west coast, and in other regions where similar fully-coupled end-to-end ecosystem models may be implemented.

Keywords: California Current; trophic interactions; end-to-end model

Oral presentation

Can volcanic-induced primary production explain high salmon returns?

Kearney K., Stock C., Tommasi D., Sarmiento J.L.

In Aug. 2008, the Kasatochi volcano, located in the Aleutian Islands, erupted. The resulting ash plume drifted over the Gulf of Alaska region, which is typically a high-nutrient, low-chlorophyll region, leading to an anomalously high bloom of diatoms. Parsons and Whitney (2012) suggest that this volcano-induced bloom may be responsible for higher than average returns of Fraser River salmon in 2010; this particular cohort of salmon would have been migrating into the Gulf of Alaska during the high productivity period. However, McKinnel (2013) counters that survival levels in this cohort were no higher than in previous years, and that the increases in diatom and mesozooplankton abundance associated with the eruption would have little effect on salmon who feed primarily on euphausiids and larval fishes; he instead attributes the high returns to a high spawner population in 2006.

Here, we use an end-to-end ecosystem model that couples physics, biogeochemistry, and food web dynamics for the subarctic Pacific food web to further investigate these competing hypotheses. The model has previously been demonstrated to capture seasonal patterns in nutrient cycling and primary production while maintaining upper trophic level populations at levels consistent with observation. It therefore provides a useful tool to quantify how volcano-induced primary production may propagate to higher trophic levels, and whether the increased salmon returns may be attributed to direct bottom-up food web processes.

Keywords: End-to-end model, salmon, Kasatochi, Pacific

Oral presentation

APECOSM, an Ocean General Ecosystem Model (OGEM) to study marine ecosystems from local to global scales. Application to the study of active and passive transport influence on global marine ecosystem dynamics

Maury O., Verley P., Gury V., Deschepper I., Guet J., Bopp L., Lefort S and Aumont O.

Global changes are modifying oceanic ecosystems at an increasing speed, leading to large-scale modifications and potential no-analogue states with unknown effects on ecological services. In this context, modelling is of prime importance to infer future changes, identify potential tipping points and derive scenarios. However, the multi-stressor nature of changes in the ocean and the multiplicity of interacting physical, chemical, biological and ecological processes at stake at various organization levels turns the responses of ecosystems to environmental forcing into a highly multidimensional and non-linear problem. Understanding its complexity and delivering reliable predictions about global marine ecosystem's future requires the development of comprehensive modelling frameworks addressing these daunting issues. These would furthermore provide theoretical basis to interpret and relate heterogeneous observations, while inspiring field studies in a focused and coordinated way. Such a mechanistic framework is not yet available however and marine ecology is still in search of its Navier Stokes equation.

In this perspective, we propose a path towards the development of an OGEM (Ocean General Ecosystem Model) that consistently relates individual, population, community and ecosystem dynamics, from local to global scales. We provide an overview of APECOSM that represents the 3D Eulerian dynamics of interactive size-structured generic Open Ocean Pelagic Communities (OOPCs: epipelagic, mesopelagic and migratory) in the global ocean, based on individual processes. These include size-structured opportunistic trophic interactions; individual bioenergetics based on DEB theory (growth, maintenance, development, reproduction), physiology (respiration, vision) and behaviour (3D movements, schooling) and includes the effects of life-history diversity in communities using a trait-based approach. Depending on the configuration used, focus species can be represented explicitly and given more details. APECOSM is coupled to a hydrodynamic (NEMO) and a biogeochemical (PISCES) model, being used to provide physical (temperature, currents) and biogeochemical (light, oxygen, phytoplankton, zooplankton, particulate organic matter) forcing to the upper trophic levels. Symmetrically, feedbacks of upper trophic levels to lower trophic levels, detritus and nutrient pools can also be considered.

As an illustration, we use of the model to investigate the effects of passive and active movements on global ecosystem distribution and size-structure. Three simulations are compared: one including both passive and active movements, one with active movements removed and one with both active and passive components of movement removed. The spatial distribution of different size of the three OOPCs is analysed and compared for the three simulations. To highlight the importance of movements and their interaction with bottom-up and top-down processes, simulated size spectrums are outputted for the three simulations in the eastern and western equatorial Pacific Ocean and in a specific region of the South Pacific subtropical gyre. We show that (1) passive movement have a major influence on the distribution of biomass for all organisms; (2) active movement have a greater impact on larger size classes; (3) movements have a strong region-specific influence

on the size-spectrum; (4) movements allow wide areas of the global ocean to sustain important biomasses while they would have been desert otherwise; (5) active movement can lead to strong regional top-down trophic cascades.

Keywords: integrated E2E model, global change, movements

Oral presentation

An integrated individual-based model as a tool for socio-ecological management of coral reefs in Indonesia

Minarro Villanueva S. and Reuter H.

With the current pace of degradation of coastal marine ecosystems, there is a pressing need for effective tools to facilitate decision-making processes for adequate management. Coral reef ecosystems are particularly sensitive to environmental and human pressures because of their exceptional biodiversity and proximity to increasingly populated coastal areas. Ecosystem services provided by coral reefs are being rapidly diminished. In often isolated tropical island states poor infrastructure and low potential for enforcement may undermine compliance of top down approaches such as fishing restrictions. In certain instances, community-based management strategies may be more feasible. Modeling is a promising means for integrating long-term data from various system compartments to examine how the complex dynamics between them shape ecosystem trajectories under different scenarios.

We present the basic structure of an individual-based model simulating the ecological trajectories of marine resources in the Spermonde Archipelago in South Sulawesi, Indonesia, under simultaneous stressors. We used a synthesized functional approach to represent the most relevant ecological compartments and feedbacks among them, focusing on the dynamic effects of human activities as a result of varying socio-economic situations. Basic competition dynamics in benthic communities are modeled as a background, incorporating fish and fishing boats as mobile agents that interact and modify each other and their environment. Socio-economic indicators for each island are used to determine the rules by which fishers select their fishing methods, areas and catch. Other common stressors such as nutrient loading and changing water temperatures are represented through different scenario settings. This model is an attempt to help managers explore the effectiveness of different conservation strategies targeted at resource users in managing coastal marine resources.

Keywords: coral reefs, management, Indonesia, individual-based modelling

Oral presentation

Understanding anchovy migration cycles in the Bay of Biscay through individual-based fish movement models

Politikos D., Huret M. and Petitgas P.

The life cycle of small pelagic populations is strongly influenced by seasonal processes as reproduction and migration, which are driven by periodic environmental variations. Modelling of fish movement behavior within a heterogeneous marine environment is a challenging but also key issue for understanding the effect of environmental factors and climatic change on fish habitat availability and connectivity occurring at the species level. Towards the building of a full life cycle fish model, the present study provides a better understanding of the mechanisms underlying anchovy annual migration behavior in the Bay of Biscay and evaluates the simulated migration patterns against spring/autumn stock distribution maps and growth histories derived from survey data. To this end, we applied a horizontal two-dimensional Individual Based Model (IBM) coupled to the ECO-MARS3D physical-biogeochemical model. Seasonal sea water temperature and zooplankton fields derived from the ECO-MARS3D were used as external forcing for the fish model. Two movement algorithms (restricted area search and kinesis) were employed to compare the anchovy distribution patterns simulated under different assumptions of fish behaviour. The Dynamic Energy Budget model (DEB) was used to represent individual growth and reproduction taking into account seasonally varying food and temperature conditions. Finally, the strengths and the key weaknesses of the adopted modelling tools will be discussed.

Keywords: movement, individual-based model, dynamic environment, DEB

Oral presentation

Modelling the early life cycle of Antarctic krill: circumpolar success and sensitivity

Thorpe S.E., Murphy E.J. and Tarling G.A.

Antarctic krill is a central species of the Southern Ocean ecosystem, being the key prey for many higher predators and having an important role in the biogeochemical cycle. Antarctic krill has a circumpolar but asymmetric distribution, with areas such as the Scotia Sea containing a significant proportion of the biomass. What determines this distribution is a fundamental question in krill ecology, with impacts for the wider food web and its management.

Work towards a full life cycle model of Antarctic krill, linked to key environmental variables, is progressing. Here we will describe results from a coupled physical-biological model of the early stages of the life cycle of Antarctic krill, encompassing embryo development to the final larval stage. The krill model is run for the circumpolar Southern Ocean, employing time-varying depth-resolved temperature and density output from the 1/6 degree eddy-permitting Southern Ocean state estimate (SOSE) model, together with satellite-derived sea ice concentration data. SOSE is a numerical ocean model of the Southern Ocean that provides a physically realistic estimate of the ocean year-round by using an adjoint method to assimilate hydrographic observations.

Results from the krill model allow us to identify areas of successful habitat for the early part of their life cycle and to examine the sensitivity to changing environmental conditions. Typical time scales in the model for development to the final larval stage of krill are upwards of three months. Over these periods, advection of the larval krill will move them through regions with different physical attributes. A particularly important attribute is the level of sea ice, which is an important habitat for overwintering larval krill, providing both food and refuge from predators. By ascertaining the likely destination of larval krill in relation to sea ice cover as they go into winter, we can determine which source regions are likely to lead to successful overwintering for the young krill and assess their vulnerability to environmental change.

Keywords: Krill, Southern Ocean, model, sea-ice, advection, life-cycle

Oral presentation

The development of an unstructured based bio-physical model to Lake Erie yellow perch recruitment

Xia M., Niu Q., Cao Z., Jiang L., Rutherford E., Schwab D.J., Anderson E.J, Pangle K., Marin Jarrin J.R., Ludsin S., Mason D.M.

Yellow perch (*Perca flavescens*; YP) is an economically and ecologically important species across the Great Lakes, which demonstrates variable recruitment to the fishery that we hypothesize is regulated by physical processes operating during early life stages. For example, Ludsin et al.'s GLFC-sponsored YP-River Discharge project has shown that Lake Erie YP recruitment success is positively correlated with Maumee River inflow and plume size during spring. However, uncertainty in predicting the distribution of these attributes, as well as their effect on movement, predation risk, consumption, growth, and survival of YP larvae in dynamic, shallow waters remains a major impediment to fully understanding and forecasting recruitment to the fishery in this system.

We built a coupled biophysical model to better understand and predict YP foraging, growth, survival, and recruitment in western Lake Erie. It is widely known that nearshore and coastal water is the important region in Great Lakes and ocean and it has complex geometry of coastline, a high-resolution unstructured grid model is required for the nearshore region. So an extant three-dimensional, wave-current, coupled Finite Volume Coastal Ocean Model (FVCOM) was used to simulate water movement in Lake Erie, particularly the western Lake Erie and its tributaries. In this study, we also present the improved water quality model and their application to Lake Erie. We will evaluate the interactive effects of river discharge and wind-driven currents on the plume and nutrient, phytoplankton and zooplankton distribution which are important to the creation and expansion of high-quality nursery habitat. The Erie model is also coupled with wave model or FVCOM-SWAVE to simulate the effect of waves on nearshore circulation and velocity fluctuations. The effect of wave to the nutrient/zooplankton dynamics is further investigated. We also calibrate and validate the model using physical (e.g., temperature, water clarity, currents) and biological (e.g., zooplankton, nutrient) data collected in western Lake Erie via prior GLFC-sponsored research and agencies (e.g., ODNR, OMNR). Overall, we found the Erie bio-physical simulation is highly sensitive to the model grid resolution; the circulation is highly sensitive to the boundary condition types; and wave is very critical to the circulation pattern, particularly under some episodes.

This model will be linked to a model of larval YP movement, foraging, growth, and survival. Few studies have been conducted to explore how physical factors influence transport and survival of fish larvae in nearshore environments of the Great Lakes. We will be using the model to test hypotheses about the influence of physical factors on larval YP transport and recruitment success by analyzing patterns of fish larvae transport, growth, and survival under various conditions, including seasonal river floods, strong wind-induced wave conditions, and fluctuating prey fields. Thus, our research will shed insight into how lake physics influence fish distributions, survival rates, and population dynamics in Lake Erie and other similar water bodies in the future.

Keywords: FVCOM, bio-physical, Erie, model
Poster presentation

Session B1: The dark ocean: recent progress in understanding the functioning of the ocean's largest subsystem

Oral Presentations

Wednesday 25 June, 16:00-17:30 Parallel session 6

Room D7

Time	Presenter	Title
16:00-16:18	Gasol, Josep	From microbial abundance to genetic and functional diversity in the deep ocean: the circumnavigation cruise Malaspina-2010
16:18-16:36	Offre, Pierre	Meta- and Single Cell Genomics of an uncultivated group of ubiquitous oceanic Thaumarchaeota indicate an organotrophic growth mode
16:36-16:54	Reinthalder, Thomas	Deep-sea prokaryotic heterotrophic biomass and production in the biogeographical provinces of the world's ocean
16:54-17:12	Varela, Marta	Dissolved inorganic carbon fixation of Thaumarchaeota vs. Bacteria in the meso- and upper bathypelagic waters of the world's oceans differentiated with the use of metabolic inhibitors
17:12-17:30	Agusti, Susana	Ubiquitous healthy diatoms in the global deep sea suggests the biological pump is efficient

Thursday 26 June, 14:00-15:30 Parallel session 7

Room D7

Time	Presenter	Title
14:00-14:18	Guerrero-Feijóo, Elisa	Prokaryotic abundance, activity and community composition in relation to the quality of dissolved organic matter in the deep waters off the Galician Coast (NW Spain).
14:18-14:36	Berman-Frank, Ilana	Dinitrogen fixation in the Mediterranean and Red Seas: New players and contributions from aphotic environments
14:36-14:54	Cavan, Emma	Particulate carbon export and transfer efficiency in the upper mesopelagic zone
14:54-15:12	Duteil, Olaf	A novel estimate of ocean oxygen utilisation points to a reduced rate of respiration in the dark ocean
15:12-15:30	Vandromme, Pieter	How do zooplankton processes affect the flux of particles? Insights from a 1D size-based NPZD model focused on zooplankton and particles dynamic.

Session B1: The dark ocean

Friday 27 June, 10:30-12:00 Parallel session 8

Room D7

Time	Presenter	Title
10:30-10:48	Santinelli, Chiara	New insights into DOM dynamics in Mediterranean deep waters
10:48-11:06	Sanders, Richard	The mesopelagic carbon budget at the PAP site
11:06-11:24	Anderson, Thomas	Reconciliation of the carbon budget in the ocean's twilight zone
11:24-11:42	Kriest, Iris	Simulating deep ocean biogeochemistry on a global scale: some aspects and challenges
11:42-12:00	Hansell, Dennis	Localized Refractory Dissolved Organic Carbon Sinks in the Deep Ocean

Poster Presentations

Wednesday 25 June, 17:30, Poster Session 2

ID	Presenter	Title
B1.P1	Zhang, Jingjing	Remineralization of particulate organic matter and consequences for the nutrients inventory in the Northern South China Sea
B1.P2	Romero, Sonia	Trophic structure of a potential marine Natura 2000 site: C and N stable isotope analysis of the deep Avilés Canyon (Cantabrian Sea, Southern Bay of Biscay)
B1.P3	Rumín Caparrós, Aitor	Biogeochemical characterization of particle fluxes in the Avilés submarine canyon, Bay of Biscay: results from a year round experiment

Ubiquitous healthy diatoms in the global deep sea suggests the biological pump is efficient

Agusti S., González-Gordillo J. I., Vaqué D., Estrada M., Cerezo M.I., Salazar G., Gasol J.M. and C. M. Duarte

Sinking rates of organic particles in the ocean represent the dominant mechanism, the so-called biological carbon pump, for sequestration of anthropogenic CO₂, involving the transport of carbon to depths below 1,000 m, where its ventilation back to the atmosphere is prevented over centennial time scales. However, sinking of organic particles is believed to be slow, rendering the biological carbon pump inefficient in most of the ocean.

During the Malaspina 2010 Circumnavigation Expedition, a global expedition sampling the bathypelagic Atlantic, Indian and Pacific Oceans, we used new approaches (including a variety of techniques), and demonstrated the presence of healthy phytoplankton cells, dominated by diatoms, to be ubiquitous in the deep sea (2000 to 4000 m depth).

We explored the community of micro-plankton (> 20 µm diameter) in the bathypelagic ocean and found these to be surprisingly dominated by phytoplankton. Well preserved cells of surface waters genera of dinoflagellates, cyanobacteria (i.e. *Trichodesmium* and picophytoplankton aggregates) were identified, with diatoms, mostly centric genera, representing however the 80% of the micro-phytoplanktonic cells found in the deep ocean. Parallel decay experiments of phytoplankton at the conditions of the dark bathypelagic ocean showed that the presence of a large proportion (18%) of healthy photosynthetic cells should be only accounted for if sinking rates were in the order of 124 to 435 m d⁻¹. These sinking rates are involving 6.8 to 24.2 days for populations sinking below the photic layer to reach 2,000 to 4,000 m, and not hundred years as assumed by simple sinking theories. Our results suggest that very fast sinking rates are not rare events in the ocean, and accelerated sinking processes are prevalent conducive to an efficient biological pump, operating across the global ocean.

Keywords: biological pump, diatoms, sinking, bathypelagic ocean

Oral presentation

Reconciliation of the carbon budget in the ocean's twilight zone

Anderson T.R., Giering S.L.C., Sanders R. and Lampitt R.S.

Biological processes in the oceans play an important role in the global carbon cycle via the export of organic matter from surface waters and subsequent remineralization at depth, a process known as the 'biological carbon pump'. The rate at which atmospheric carbon is exported to depth and remineralized by heterotrophic organisms is an important control over air-sea carbon dioxide (CO₂) partitioning, keeping atmospheric CO₂ significantly lower than it would be if the oceans were abiotic. The bulk of sinking particles are processed by microbes and zooplankton in the twilight zone (50-1000 m) and it is their relative contributions to particle remineralization that ultimately determine carbon export efficiency. Recent observations (presented elsewhere at this meeting; Giering et al.) permitted the construction of a balanced carbon budget of sinks and sources of organic carbon in the twilight zone, by applying a simple mass balance approach. Using this data set, we employ a steady state numerical model to explore the cycling of carbon in the interior and show that the observations are consistent with prokaryotes being responsible for ca 80% of estimated twilight zone remineralization, despite much of the organic carbon being supplied as large, fast-sinking particles that are readily accessible to larger zooplankton. This high contribution of prokaryotes to remineralization occurs because much of the organic matter processed by zooplankton is broken up and released, rather than being remineralized, thereby stimulating the deep-ocean microbial loop. The synergy between microbes and zooplankton is key to understanding the working of the oceanic carbon sink, suggesting that any restructuring of the mesopelagic foodweb would likely lead to a rebalancing of inorganic carbon inventories between ocean and atmosphere.

Keywords: mesopelagic zone, carbon budget, ecosystem model

Oral presentation

Dinitrogen fixation in the Mediterranean and Red Seas: New players and contributions from aphotic environments

Berman-Frank I., Rahav E., Herut B. and Mulholland M.

In the last ten years biological dinitrogen (N_2) fixation rates have been measured across the Mediterranean and diverse populations of diazotrophs (N_2 fixers) have been elucidated. A review of published data demonstrates that in the upper photic zone the actual contribution of N_2 fixation to new and total production ranged from 1-2% in the easternmost Levantine Basin to ~50% of new production during the stratified summer months in the north western Mediterranean. Here, we measured N_2 fixation rates from oceanic zones that have traditionally been ignored as sources of biological N_2 fixation; the aphotic, fully oxygenated, nitrate (NO_3^-)-rich, waters of the oligotrophic Levantine Basin. N_2 fixation rates measured from pelagic aphotic waters to depths up to 720 m, during the mixed and stratified periods ranged from $0.01 \text{ nmol N L}^{-1} \text{ d}^{-1}$ to $0.38 \text{ nmol N L}^{-1} \text{ d}^{-1}$ and correlated significantly with bacterial productivity. Diverse heterotrophic diazotrophs were identified from aphotic as well as photic depths. Dissolved free amino acid amendments to whole water from the enhanced bacterial productivity and N_2 fixation rates illustrating that both BP and heterotrophic N_2 fixation are carbon limited. Experimental manipulations of aphotic waters from the LB demonstrated a significant positive correlation between transparent exopolymeric particles (TEP) concentration and N_2 fixation rates. This suggests that sinking organic material and high carbon (C): nitrogen (N) micro-environments (such as TEP-based aggregates or marine snow) could support high heterotrophic N_2 fixation rates in oxygenated surface waters and in the aphotic zones. Indeed, our calculations show that aphotic N_2 fixation accounted for 37 to 75 % of the total daily integrated N_2 fixation rates from locations in the Mediterranean and Red Seas with rates equal or greater to those measured from the photic layers. Our results indicate that while N_2 fixation may be limited in the surface waters, aphotic, pelagic N_2 fixation may contribute significantly to new N inputs in other oligotrophic basins, yet it is currently not routinely measured or included in regional or global N budgets.

Keywords: dinitrogen-fixation, aphotic, diazotrophs, N-cycling,

Oral presentation

Particulate carbon export and transfer efficiency in the upper mesopelagic zone

Cavan E.

The drawdown of atmospheric CO₂ into the deep ocean occurs via the production and sinking of organic carbon from the upper ocean. During downward transport the magnitude of particulate organic carbon (POC) decreases exponentially due to remineralisation by zooplankton and bacteria. Little is known about what controls the variation in remineralisation between season and region yet simple global algorithms using satellite-derived mixed layer chlorophyll, primary production and temperature are often used to estimate the magnitude and composition of POC fluxes. Here I present carbon flux data from the upper mesopelagic zone (depth range 40-350 m) from three different oceanographic regions; Southern Ocean, Porcupine Abyssal Plain (North Atlantic) and the Eastern Tropical North Pacific oxygen minimum zone. Marine snow catchers were deployed at each location to collect large particles which had sunk to the base. Particles were distinguished as phytodetrital aggregates or zooplankton faecal pellets identifying dominance of particle type in carbon flux depending on region and season. Particle export efficiency and Martin's b (a proxy for transfer efficiency) were calculated and compared within and between each region. Whilst determining the magnitude of carbon fluxes on short time scales may be relatively straight forward, interpreting the controls and calculating long time scale estimates is not as simple. Providing sensible estimates of carbon export from the surface to the deep ocean via in situ sampling is crucial in a time when predicting the future state of the ocean is vital.

Keywords: carbon export flux remineralisation

Oral presentation

A novel estimate of ocean oxygen utilisation points to a reduced rate of respiration in the dark ocean

Duteil O., Koeve W. and Oschlies A.

The Apparent Oxygen Utilisation (AOU) is a classical measure of the amount of oxygen respired in the ocean interior. We show that AOU systematically overestimates True Oxygen Utilisation (TOU) in 6 coupled circulation-biogeochemical ocean models. This is due to atmosphere–ocean oxygen disequilibria in the subduction regions, consistent with previous work. We develop a simple, new, observationally-based approach which we call Evaluated Oxygen Utilisation (EOU). In this approach, we take into account the impact of the upper ocean oxygen disequilibria into the interior, considering that transport takes place predominantly along isopycnal surfaces. The EOU approximates the TOU with less than half of the bias of AOU in all 6 models despite large differences in the physical and biological components of the models. Applying the EOU approach to the World Ocean Atlas global observational dataset yields an oxygen consumption rate 25% lower in the interior ocean than that derived from AOU-based estimates, for a given ventilation rate. This impacts significantly the estimated concentration of regenerated and preformed phosphate in the dark ocean.

Keywords: respiration, AOU, regenerated nutrients

Oral presentation

Prokaryotic abundance, activity and community composition in relation to the quality of dissolved organic matter in the deep waters off the Galician Coast (NW Spain).

Guerrero-Feijóo E., Nieto-Cid M., Álvarez-Salgado X.A., Álvarez M., Hernando-Morales V., Sintés E., Teira E., Herndl G.J. and Varela M.M.

We have simultaneously studied the abundance, activity and prokaryotic community structure in relation to the quality of oceanic dissolved organic matter (DOM) in the meso- and bathypelagic waters off the Galician Coast (NW Spain, from 43°N, 9°W to 43°N, 15°W). Distinct water masses were identified based on their physical and chemical characteristics. While prokaryotic heterotrophic production decreased from the euphotic layer to the bathypelagic waters by two orders of magnitude, prokaryotic abundance decreased only by one order of magnitude. The relative abundance of SAR11 and *Alteromonas*, determined by catalyzed reported deposition fluorescence in situ hybridization (CARD-FISH) decreased with depth, while the contribution of SAR 202 and SAR324 to total bacterial abundance as well as the percentage of total prokaryotes identified as Crenarchaeota was significantly higher in the deeper layers (NEADW, North East Atlantic Deep Water and LDW, Lower Deep Water) than in the euphotic zone. Bacterial abundance showed a positive correlation with the absorption coefficient at 254 nm and the dissolved organic carbon, while was negatively correlated to marine humic-like substances. Crenarchaeotal abundance was correlated positively to protein-like fluorescence and the molecular weight of the DOM. On the other hand, Bacterial and archaeal community structure were analyzed by ARISA (automatic rRNA intergenic spacer analysis) and T-RFLP (terminal restriction fragment length polymorphism) fingerprints respectively. Both bacterial and archaeal community structures were depth-stratified, with a total of 305 and 48 operational taxonomic units (OTUs) respectively, as revealed. A linear model approach (DISTLM,) revealed that the variability found in both bacterial and archaeal community was mainly described by nitrate, phosphate, temperature, coloured and fluorescent DOM, prokaryotic abundance and prokaryotic leucine incorporation. Our results displayed a prokaryotic community structure based not only on depth-related physicochemical features but also on DOM quality, indicating that different prokaryotic taxa have the potential to metabolize specific DOM sources.

Keywords: prokaryotic community structure, DOM, CARD-FISH

Oral presentation

Prokaryotic abundance, activity and community composition in relation to the quality of dissolved organic matter in the deep waters off the Galician Coast (NW Spain).

Guerrero Feijóo E., Álvarez Salgado X.-A., Álvarez M., Hernando Morales V., Sintés E., Teira E., Herndl G.J. and Varela M.M.

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Keywords: prokaryotic community structure, DOM, CARD-FISH

Oral presentation

Localized refractory Dissolved Organic Carbon sinks in the Deep Ocean

Hansell D.A. and Carlson C.A.

The global ocean holds one of Earth's major carbon reservoirs as dissolved organic matter (662 ± 32 PgC). Most of this material (>95%) is termed refractory dissolved organic carbon (RDOC) as it is old relative to the circulation time of the ocean. While RDOC within the modern ocean has been perceived as vast and only slowly renewed, its mobilization has been implicated to explain Earth's transient warming events (i.e., hyperthermals) of the Paleocene and Eocene epochs (65-34 million years ago). Assessing this proposed function of RDOC as a rapidly (~ 5 - 10 K y) exchangeable carbon reservoir is presently limited by insufficient knowledge of responsible processes. Here we investigate the dynamics of RDOC in the deep Pacific Ocean, previously characterized by concentration gradients thought to be established by slow but systematic RDOC removal with circulation and aging of the water masses. We demonstrate that RDOC is instead conserved during much of its circulation, but that there exist localized sinks in the deep, far North Pacific and at mid-depth in the subtropical South Pacific. Water mass mixing into these sink regions creates the observed RDOC gradients. Together the Pacific sinks remove 7-29% of the 43 Tg RDOC added to the deep global ocean each year with overturning circulation, and point to an important but still unidentified control on the RDOC inventory of deep marine systems.

Keywords: carbon, DOC, refractory DOC, sinks

Oral presentation

Remineralization of particulate organic matter and consequences for the nutrients inventory in the Northern South China Sea

Zhang J.J., Chen J. and Li H.

Sediment trap data have been used to study fluxes and processes of settling particles in the ocean interior in order to better understand the biological pump. However, such study is still lacking in the South China Sea (SCS) which is characterized as a typical semi-enclosed marginal sea in the East Asian Monsoon region. Based on particulate organic carbon (POC) fluxes attained from deep time series sediment trap, reported export production of euphotic zone and nutrients concentrations in the water column associated with residence time in the northern basin of SCS, a transfer efficiency (Teff) of POC between euphotic zone and 1000 m layer and contributions of organic matter remineralization to nutrients are calculated in this study. Our results show that the annual averaged Teff is 13.79%, and compared with two VERTIGO sites, it's higher than ALOHA station but lower than K2 station during summer. Furthermore, we also revise the regulation that POC flux decreases with depth (analogous Martin curve) to make it available in the northern basin of SCS. Finally, the contributions derived from organic matter remineralization to nutrients inventory within different residence times of water columns have been estimated about 39.4% of Nitrogen and 35.6% of Phosphorus in 100 m-350 m column, 19.3% of Nitrogen and 16.7% of Phosphorus in 350 m-1000m column respectively.

Keywords: SCS, sediment trap, POC flux, remineralization, nutrient

Poster presentation

Simulating deep ocean biogeochemistry on a global scale: some aspects and challenges

Kriest I. and Oschlies A.

The combined effects of physical transport processes, export production and remineralization profiles on long time scales strongly determine the global distribution of deep oxygen and nutrients, as demonstrated by various model studies. Benthic burial, as expressed through a model's lower boundary condition, may mediate this dependency, and lead to a reduced sensitivity of simulated dissolved oxygen to changes in particle sinking speed or decay rate. Here we examine different global model studies of varying resolution and biogeochemical setup for their response to changes in these parameters, with focus on deep tracer distributions and fluxes. We show that under certain assumptions simulated deep oxygen is more sensitive to changes in remineralization length scale than e.g., phosphate. A higher "robustness" of oxygen towards this parameter comes on the cost of mismatches in benthic fluxes of organic matter in some regions, or mismatches in other oxidants that replace oxygen. These results, and the implications for further studies, are discussed in the light of projected future increase of suboxic areas in the ocean.

Keywords: global biogeochemical model, remineralization, oxygen

Oral presentation

Meta- and Single Cell Genomics of an uncultivated group of ubiquitous oceanic Thaumarchaeota indicate an organotrophic growth mode

Offre P., Weinmaier T., Rattei T., Swan B.K., Stepanauskas R., Herndl G.J. and Schleper C.

Archaea represent a major component of microbial communities thriving in oceanic waters, where members of the Thaumarchaeota phylum constitute the dominant group of archaea. Thaumarchaeota are ubiquitous and particularly dominant in the dark ocean, accounting for up to 25% of all microbial cells. Most thaumarchaeal organisms in oceanic waters belong to the Marine Group I (also referred to as group 1.1a) but between 2 and 10% of all thaumarchaeal cells are related to the Marine Benthic Group A (MBG-A), which is present throughout the water column and ubiquitously distributed in the global ocean. While cultivated representatives of the Marine Group I grow autotrophically by oxidizing ammonia to nitrite, the physiology and ecological function of members of MBG-A are currently unknown.

The aim of this study is to determine the metabolic potential of dark ocean representatives of MBG-A. A metagenomic approach was used to reconstruct the genomes of these organisms. Three samples, each from a different depth (776, 2750 and 5000m) were collected from three stations in the Subtropical Northeast Atlantic (SNA). MBG-A representatives were present at all sites and depths and three almost complete genomes were reconstructed from approx. 126 Gb of paired-end sequence data. Two MBG-A single cells, also sampled from SNA waters, were sequenced and corresponding single cell genomes supported our genome reconstruction approach and delivered additional genomic information. Annotated genes suggest that these archaea are most probably not ammonia oxidizers and instead are versatile organotrophs growing aerobically on sugars, short-chain fatty acids and possibly aromatic compounds. This indicates that certain marine thaumarchaeal organisms are also involved in the cycling of organic matter. Additional analyses will be presented to further discuss the ecological niche of this enigmatic group of archaea.

Keywords: Archaea, Dark Ocean, Organotrophy, Metagenomics, SCG

Oral presentation

Deep-sea prokaryotic heterotrophic biomass and production in the biogeographical provinces of the world's ocean

Reinthal T. and Yokokawa T.

It is still an open question whether the classification into oceanic biogeographical provinces, generally based on the physical and biological characteristics of the sunlit surface waters, is also reflected in dark ocean microbial processes. Here we collated a global dataset of prokaryotic biomass and heterotrophic production measurements from a depth range of 200 – 4000 m to test whether provincialism constrains the dark ocean heterotrophic community. Comparing modeled particulate organic carbon fluxes with microbial standing stock in the meso- and bathypelagic waters of the global dataset indicated a link between the particle rain and prokaryotic biomass. In the bathypelagic, a fraction of the prokaryotic heterotrophic production was explained by the particle flux, however, the relationship for the mesopelagic was weak.

Significant differences between biogeographical provinces of depth integrated prokaryotic biomass and production were found. Yet the extent of prokaryotic biomass and production suggested a pattern corresponding to larger scale biomes rather than to the Longhurst scheme of oceanic provinces.

Our results indicate that the generally higher productive northern provinces are primarily influenced by sinking organic matter derived from the surface layers. In contrast, buoyant or slowly sinking particles and dissolved organic matter partly originating from the source water regions might be relatively more important in the oligotrophic gyre. This points to the need of incorporating water mass mixing models to decipher the interplay of the surface derived particle rain and water mass transport on prokaryotic biomass and heterotrophic production.

Keywords: Dark Ocean, prokaryotic biomass, heterotrophic production

Oral presentation

Trophic structure of a potential marine Natura 2000 site: C and N stable isotope analysis of the deep Avilés Canyon (Cantabrian Sea, Southern Bay of Biscay)

Romero S., Molina Ramírez A., Höfer J. and Acuña J.L.

A large taxonomic effort is being devoted to document the diversity of potential Sites of Community Importance (SCIs) which will complete the network of European marine Natura 2000 sites by year 2020. This includes the Avilés Canyon (AC), a deep submarine trench that crosses the narrow Cantabrian Shelf West of Cape Peñas and that hosts diverse deep coral habitats and rich populations of invertebrates, fishes, cetaceans, birds and giant squids. However, efficient management of those sites requires not only precise taxonomic information, but also knowledge on functional attributes like their spatial distribution, trophic structure and complexity, sources of matter and energy, or the degree of relationship with their terrestrial counterpart. Stable isotopes offer a simple, synthetic methodology that does not involve labour intensive analyses and can therefore be used to produce simplified snapshots of the trophic structure of an ecosystem. Within the activities of project BIOCANT/DOSMARES, we have conducted a stable isotope analysis of specimens collected at the AC area from a variety of zones (benthic, pelagic), taxa (from phytoplankton through invertebrates and fishes to giant squids and cetaceans) or depths (from 0 to 4700 m).

According to this analysis, $\delta^{13}\text{C}$ ratios of pelagic organisms ($-20.2 \pm 1.3\text{‰}$, mean \pm SD) point to phytoplankton ($-19.2 \pm 1.5\text{‰}$) as their main food source. $\delta^{13}\text{C}$ for benthic organisms varied between -18 and -14‰ , well below the measured value for terrestrial sediments and riverine POM (ca. -26‰), which suggests that either runoff material is processed in its travel along the AC, or that there are other sources of organic matter available in the deep ocean. Using copepods as $\delta^{15}\text{N}$ baseline (TL=2) and assuming a 3.4‰ of trophic level enrichment, our data indicate that the AC ecosystem spans 4 trophic levels, with phytoplankton at the bottom ($\delta^{15}\text{N} = 2.3 \pm 0.8 \text{‰}$, TL=0.6) and echinoderms at the top ($\delta^{15}\text{N} = 13.3 \pm 2.3 \text{‰}$, TL = 3.9), in absence of data for birds, giant squid and cetaceans which are currently being obtained. In spite of their small size, chaetognaths had the highest TL3.1 among pelagic taxa, what confirms their predatory status. However, demersal fishes had a TL=3.4, similar to that of benthic invertebrates like polychaetes, but much lower than expected from their marked predatory role. Their swimming ability might allow those fishes some independence from the sediment and the high $\delta^{15}\text{N}$ of its associated organic matter. Trophic level increased with body size, as estimated from wet weight, relationship very similar to that obtained in other marine ecosystems, what points to a potential cross-system generalization.

Keywords: Avilés Canyon, Food Web, Stable Isotopes

Oral presentation

Biogeochemical characterization of particle fluxes in the Avilés submarine canyon, Bay of Biscay: results from a year round experiment

Rumín Caparrós A., Sanchez Vidal A., Calafat A. and Canals M.

DOSMARES (Deep-water submarine canyons and slopes in the Mediterranean and Cantabrian seas: from synchrony of external forcings to living resources) is a project aimed at improving knowledge on the benthic and pelagic habitats of submarine canyons and deep slopes in the seas around the Iberian Peninsula, with strong emphasis in the almost unknown Avilés submarine canyon. With the purpose of investigating which oceanographic processes regulate particulate matter transport in the Avilés submarine canyon and the adjacent slope, two consecutive deployments of an array of three mooring lines equipped with near-bottom sequential sampling sediment traps, high-accuracy conductivity-temperature recorders and current meters were deployed from March 2012 to April 2013 at 2000 and 4700 m depth along the canyon axis and at 1200 m in the outer western slope. The material collected by the sediment traps has been processed in the laboratory to obtain total mass fluxes and main constituents (lithogenics, calcium carbonate, opal and organic matter) content. The integrated analysis of sediment trap and current-meter data together with remote sensing images, and meteorological and hydrographical data has allowed us to better understand the sources and the processes controlling the transfer of particulate matter into the Aviles submarine canyon and its adjacent slope. Tidal spectra analysis of current-meter data has shown that frequency variations on currents were stronger at semidiurnal frequencies elucidating that during most of the studied year settling particles in the Aviles Canyon and on its adjacent slope were under the influence of tidal currents. Biogeochemical characteristics of particles indicate that riverine inputs represent the principal source of particles arriving to the studied area. Upwelling events driven by southwestwards winds are the principal mechanism by which shelf and slope deposited riverine sediments are resuspended and transported down canyon. In addition, high resolution bathymetry suggest that the Aviles Canyon head, which is located in a short distance from the shoreline and close to the Nalon and Narcea's river mouth, acts as a zone of sediment bypass due to the alongshore westward current acceleration around the Cabo Peñas headland. Thus, suspended material is mainly funnelled through La Vallina Branches network located in the western flank of the Avilés submarine canyon.

Keywords: Sediment transport, Avilés submarine canyon

Poster presentation

The mesopelagic carbon budget at the PAP site

Giering S., Sanders R., Lampitt R., Anderson T., Henson S. and Saw K.

The global carbon cycle is affected by biological processes in the oceans, which export carbon from surface waters in the form of organic matter and store it at depth; a process called the 'biological carbon pump'. Most of the exported organic carbon is processed by the biota in the mesopelagic zone (50-1000 m), which ultimately converts it into CO₂ via respiration. Variations in the resulting decrease in organic flux with depth can, according to models, lead to changes in atmospheric CO₂ of up to 200 ppm. Attempts to balance the carbon budget in the mesopelagic zone have however failed, with discrepancies of up to an order of magnitude between observed losses of organic carbon and community metabolism. Here we describe a revised carbon budget for the mesopelagic from the Porcupine Abyssal Plain site (49°N, 16.5°W), NE Atlantic, which balances to within observational uncertainties. This balance was achieved by (1) assuming that all zooplankton that undertake diel vertical migration source their organic carbon from within the mixed layer; (2) integrating processes from the base of the mixed layer (50 m) rather than from a deeper level as has previously been done; and (3) computing zooplankton respiration rather than carbon demand. Overall we suggest that the existing paradigm of an apparently inadequate supply of organic carbon to the mesopelagic zone requires revision.

Keywords: Zooplankton carbon twilight, bacteria sinking model

Oral presentation

New insights into DOM dynamics in Mediterranean deep waters

Santinelli C., Follett C., Retelletti Brogi S., Xu L., Galletti Y. and Repeta D.

The Mediterranean Sea shows some peculiar aspects that make it a natural laboratory to investigate DOM dynamics in the dark realm. Each winter, deep water formation occurs in Adriatic Sea and Gulf of Lions, driven by high local salinity and the heat loss due to strong, cold regional winds. Deep waters are characterized by temperatures $\sim 10^{\circ}\text{C}$ higher than in the open ocean and by enhanced respiration and DOC mineralization rates.

A synthesis of the information about DOC dynamics in deep waters will be presented and discussed together with the first DOC radiocarbon data available for the basin and new CDOM data for Mediterranean deep waters.

One of the most intriguing aspect of DOC dynamics in the Mediterranean Sea is that between 500 m and the bottom, DOC values reach as low as 36-44 μM , comparable to values observed in the deep open ocean, even though the residence time of water in the Mediterranean are only 10-100s years. This finding can be explained by a different functioning of the microbial loop, with a more efficient mineralization of DOC, and by higher temperatures ($12-13^{\circ}\text{C}$) that may promote faster respiration, and/or by different communities of heterotrophic prokaryotes. Another hypothesis is that in the Mediterranean Sea, the concentration of refractory DOC (RDOC) is lower than 36 μM .

DOC is also somewhat elevated in the near bottom waters, with highly variable concentrations in the areas subject to intrusions of recently ventilated deep water. The high DOC concentrations together with the high DOC removal rates suggest that the fraction of DOC exported to depth is semi-labile.

Focusing on RDOC, the less understood but most important fraction for long-term C storage, its dynamics suggests that some removal mechanisms are faster in the Mediterranean Sea than in the open ocean. Assuming that 40 μM represents the RDOC in the Mediterranean Sea as well as in the Atlantic Water entering the Med Sea, a net inflow of RDOC at the Gibraltar Strait of $0.027\mu\text{M C year}^{-1}$ can be estimated. Assuming no removal or removal rates similar to those estimated for the oceans, it would take a period of ~ 1500 years to reach a Mediterranean RDOC concentration of 40 μM . Since the Med Sea was refilled by the AW about 5.33 million years ago, RDOC removal mechanisms are probably occurring in the Med Sea, otherwise the RDOC concentration would be markedly higher.

The similarity in DOC age between the Med sea and open oceans raise new intriguing questions on DOC cycle in the Med Sea.

Keywords: Dissolved organic carbon, CDOM, Mediterranean Sea

Oral presentation

How do zooplankton processes affect the flux of particles? Insights from a 1D size-based NPZD model focused on zooplankton and particles dynamic.

Vandromme P., Kriest I. and Stemmann L.,

The way detritic particles are processed through the dark ocean is a complex mechanism with worldwide consequences, impacting notably the strength of the biological carbon pump, and is, moreover, a challenging modeling exercise. The development of size-structured models of particles over traditional box ones leads to more realistic estimates of the particles flux, yet, an important part of the observed variability is not represented (Stemmann and Boss, 2012). The lack of complexity and realism in the formulation of the zooplankton compartment is a possible source of discrepancy between actual models and observations. In the present work we present a 1D NPZD model where phytoplankton, zooplankton and detritus are size-structured. The formulation of detritus includes coagulation, fragmentation, remineralization and sedimentation processes as well as main interactions with zooplankton (feeding on detritus, production of fecal pellets, active transport by diel vertical migration). The zooplankton is separated in two groups based on their feeding behavior, and are both size-structured. The first group consists in selective feeders and is able to search the water column for large detritus. This group will also selectively feed on phytoplankton and other zooplankton. The second group consists in unselective feeders, which exhibits a filter-feeding behavior. This separation allows representing the various ways zooplankton of different sizes feed on detritus. Using the UVP5 dataset of size-structured observations on particles and zooplankton (Picheral et al. 2010) we tested the sensitivity of the model at contrasted locations to assess the variability in the export flux potentially due to zooplankton related processes.

Picheral, M., Guidi, L., Stemmann, L., Karl, D. M., Iddaoud, G., & Gorsky, G. (2010). The Underwater Vision Profiler 5: An advanced instrument for high spatial resolution studies of particle size spectra and zooplankton. *Limnology and Oceanography: Methods*, 8(1), 462–473. doi:10.4319/lom.2010.8.462

Stemmann, L., & Boss, E. (2012). Plankton and Particle Size and Packaging: From Determining Optical Properties to Driving the Biological Pump. *Annual Review of Marine Science*, 4(1), 263–290. doi:10.1146/annurev-marine-120710-100853

Keywords: Zooplankton, Particles, Size-structured model, Biological pump

Oral presentation

Dissolved inorganic carbon fixation of Thaumarchaeota vs. Bacteria in the meso- and upper bathypelagic waters of the world's oceans differentiated with the use of metabolic inhibitors

Varela M.M., Herndl G.J., Sintes E., Teira E. and Gasol J.M.

Recent studies suggest that the dark ocean prokaryotes fix inorganic carbon at rates substantially higher than assumed. We have studied the contribution of Archaea vs. Bacteria to total prokaryotic fixation of dissolved inorganic carbon (DIC) in the meso- and upper bathypelagic waters of the world's oceans during the Malaspina circumnavigation expedition carried out between December 2010 and July 2011. We used the metabolic inhibitor Erythromycin, an antibiotic specifically inhibiting growth of Bacteria but not affecting Archaea. Bacteria dominated throughout the water column in the three major ocean basins (54% of the total DAPI counts), decreasing in their relative contribution to total prokaryotic abundance from the surface to the meso- and bathypelagic waters. By contrast, the relative contribution of Thaumarchaeota was generally higher in the meso- and bathypelagic layers than in the surface waters (up to 29% of the total DAPI counts in the Pacific Ocean). Averaged over the entire water column, Thaumarchaeota contributed 8%, 33% and 18% to the total prokaryotic DIC fixation in the Indian, Pacific and Atlantic Ocean, respectively. The contribution of Thaumarchaeota to total prokaryotic DIC fixation increased with depth, particularly in the Atlantic below 1000 m depth and in the lower mesopelagic zone of the Pacific Ocean. Preliminary results from an station in the Atlantic Ocean, combining microautoradiography and fluorescence in situ hybridization (MICRO-CARD-FISH), confirmed that both Thaumarchaeota and some bacterial groups such as SAR 324 take up DIC. Thaumarchaeota and SAR 324 accounted for 7 % and 12% of DIC-positive DAPI-stained cells, respectively, as revealed by MICRO-CARD-FISH. Our results suggest that some phylogenetic groups may be significant contributors to the dark ocean chemoautotrophy.

Keywords: world oceans, Thaumarchaeota, Bacteria, chemoautotrophy, MICRO-CARD-FISH

Oral presentation

Session B2: Microbial and geochemical perspectives of global carbon cycling and climate change: from genes to ecosystems, from ancient to current

Oral Presentations

Tuesday 24 June, 11:00-12:30 Parallel session 1

Room K3

Time	Presenter	Title
11:00-11:30	Jiao, Nianzhi	Microbial regulations of ocean carbon sink: perspectives and testable hypothesis
11:30-11:45	Legendre, Louis	Significance of the Microbial Carbon Pump in the Globally Changing Ocean
11:45-12:00	Luo, Genming	Timing the formation of the large DOC reservoir in the Ediacaran oceans
12:00-12:15	Dautovic, Jelena	Long Term Fluctuation of Organic Matter in the Northern Adriatic Sea: Possible Barometer of Global Changes
12:15-12:30	François, Roger	Organic Carbon Flux in the Mesopelagic Zone at Station Papa Estimated From ²³⁴ Th and ²³⁰ Th Measurements in Different Particle Size Classes

Tuesday 24 June, 14:00-15:30 Parallel session 2

Room K3

Time	Presenter	Title
14:00-14:15	Kattner, Gerhard	Microbial formation of marine dissolved organic matter: recalcitrant or labile?
14:15-14:30	Marrase, Celia	The major constraint for total DOM remineralization in the dark ocean: Quality, quantity or diversity of organic matter?
14:30-14:45	Stedmon, Colin	Why does dissolved organic matter persist in the deep ocean? Is part of the solution, dilution?
14:45-15:00	Tremblay, Luc	Rapid degradation of particulate and dissolved organic matter in a naturally iron-fertilized region of the Southern Ocean
15:00-15:15	Frischer, Marc	Linked carbon and nitrogen cycling in the coastal Arctic, will organic carbon release from thawing permafrost impose bacterial nitrogen limitation?
15:15-15:30	Dang, Hongyue	Diverse novel bacteria and archaea contributing to urea utilization in the surface sediments of the Bohai Sea, China

Session B2: Microbial and geochemical perspectives

Tuesday 24 June, 16:00-17:30 Parallel session 3
Room D7

Time	Presenter	Title
16:00-16:15	Obernosterer, Ingrid	Link between microbial diversity and productivity in a mosaic of phytoplankton blooms
16:15-16:30	Pree, Bernadette	Growth, production and microzooplankton grazing on heterotrophic bacteria during different phases of a <i>Phaeocystis pouchetii</i> bloom
16:30-16:45	Zeng, Qinglu	The Effect of Phage Infection on Cyanobacterial Central Carbon Metabolism
16:45-17:00	Zhang, Chuanlun	Change in community structure of planktonic Archaea from the lower Pearl River to the Northern South China Sea: Implications for archaeal ecological functions in different habitats
17:00-17:15	Arandia Gorostidi, Nestor	Light stimulates the growth rates of diverse phylogenetic groups of marine heterotrophic bacterioplankton
17:15-17:30	All	General Presentation

Poster Presentations

Tuesday 24 June, 17:30, Poster Session 1

ID	Presenter	Title
B2.P1	Luo, Genming	Probing microbial carbon pump in ancient oceans
B2.P2	Zhang, Zilian	Production of exopolysaccharide by marine bacteria
B2.P3	Zeri, Christina	DOC dynamics and CDOM fluorescence in the interconnected Marmara - North Aegean Seas
B2.P4	Thomas, Helmuth	Unravelling Carbon Fixation under Nutrient limited Conditions - a Water Column Perspective
B2.P5	Xu, Yongle	Comparative genome analysis of three marine roseophages, new insights into the link of genes and environment

Light stimulates the growth rates of diverse phylogenetic groups of marine heterotrophic bacterioplankton

Arandia Gorostidi N., Huete Stauffer T. M., Morán X.A.G. and Alonso-Sáez L.

The widespread presence of light-harvesting mechanisms (such as proteorhodopsins) in bacterioplankton is one of the most exciting discoveries in marine microbial ecology in recent years. Proteorhodopsins enable marine bacteria to use light as an extra energy source in addition to organic compounds, which, hypothetically, may promote their growth. However, the direct effect of light promoting the growth rate of proteorhodopsin-containing bacteria has only been shown in a cultured strain of Flavobacteria (*Dokdonia* sp. MED134) to date, with no conclusive results in other taxa or marine environmental communities. In order to understand the response of specific phylogenetic groups of bacterioplankton to the availability of light, we performed 12 monthly incubation experiments in 2012 under light and dark conditions. For each experiment, two treatments were assessed: C, water pre-filtered by 200 μm containing the whole microbial community and F, water filtered by 0.8 μm to remove phytoplankton and bacterial grazers. As the filtered treatment effectively removed the phytoplanktonic cells in the incubations, they served as a control to exclude the possibility that increases in bacterial growth were associated with increases in primary production, rather than a direct effect of light as energy source. The single-cell method Catalyzed Reporter Deposition Fluorescence In Situ Hybridization (CARD-FISH) was used to determine changes in the abundance of broad phylogenetic bacterial groups: Gammaproteobacteria, Bacteroidetes and Alphaproteobacteria together with two more specific alphaproteobacterial members, Rhodobacteraceae and SAR11. Growth rates were calculated for the exponential phase during 5-9 days of incubation. Light consistently influenced the growth of marine Bacteroidete in the incubations, with mean growth rates in the C treatment under light of 1.07 d^{-1} as compared with 0.60 d^{-1} in dark conditions. The direct effect of light on the growth of Bacteroidetes was still visible in the F treatment (0.86 vs. 0.70 d^{-1}), where phytoplankton was absent. The highest difference in growth rates for both treatments was observed in May, likely related to the in situ high abundance of a proteorhodopsin-containing member of Bacteroidetes (*Tenacibaculum*) on that date. In some months, increases in the growth rates of Rhodobacteraceae and SAR11 were also observed under light, indicating that the growth of these widespread marine clades can be enhanced by light under certain conditions. This work is the first direct evidence of light promoting the in situ growth of different marine bacterial clades.

Keywords: Bacterioplankton, light, growth, bacteroidetes, Sar11, Rhodobacteraceae

Oral presentation

Diverse novel bacteria and archaea contributing to urea utilization in the surface sediments of the Bohai Sea, China

Dang H.

Urea is usually the most abundant single chemical species of dissolved organic nitrogen, contributing 50% or more to the total N requirement of the aquatic primary producer communities in many coastal waters. Marine animals excrete urea as a waste product of cellular metabolism. In coastal oceans, urea from anthropogenic sources such as fertilizers can also enter the aquatic ecosystems as terrestrial runoff. The urea dynamics may influence the species composition, community structure, abundance and productivity of marine phytoplankton assemblages. Anthropogenic urea transported to sensitive estuarine and coastal waters may cause aquatic eutrophication and harmful algal blooms (HABs). Excessive urea may stimulate the growth and toxin production of HAB-forming species. Thus, urea is an important form of nutrient, environmental pollutant or catastrophe-triggering substance in different coastal ecosystems. Although ureolytic microorganisms may play important roles in N cycling in marine environments, little is known about their ecological characteristics and environmental response in the world's major coastal oceans. The Bohai Sea is the most polluted and overexploited coastal ocean in China. How the different pollutants influence the diversity, community structure, distribution, abundance and activity of the sediment ureolytic microorganisms is currently unknown. The Bohai Sea may serve as a large model system to study ureolytic microbial eco-functionality and pollutant biogeochemical transformation, to gain insightful knowledge for marine environment management and remediation. In this study, an ocean-wide investigation of the sediment ureolytic bacteria and archaea communities was carried out in the Bohai Sea, with key environmental factors that may shape the ureolytic microbiota being also analyzed.

Keywords: urea, urease, archaea, ammonia oxidation, sediment

Oral presentation

Long term fluctuation of organic matter in the northern Adriatic Sea: Possible barometer of global changes

Dautović J., Vojvodić V., Čosović B. and Ciglencčki I.

One of the Earth's largest reservoirs of organic matter in the sea, dissolved organic carbon (DOC) provides a substrate for life, and is a source for nutrient regeneration, ion exchange capacity, light and heat absorption. Increased measurements accuracy enables detection at concentrations gradients and basin-scale difference, opening its use as a new geochemical tracer. Marine organic carbon represents a dynamic component in the global carbon cycle and is now recognised as an important component of the biochemical system and possibly as barometer of the global change.

Shallow northern Adriatic Sea (NA) is characterized by marked seasonal and long-term fluctuations of oceanographic and biological conditions, mainly due to atmospheric forcing: Po River freshwater discharges from the western coast, advection of oligotrophic central Adriatic waters along the eastern coast, and a very variable and complex circulation. In the period from 1988 in the NA massive formation of organic aggregates reported as "mucilage phenomenon" occurred with increased frequency^{1,2}. The intensity of this phenomenon varied over the years: (1988, 1991, 1997, 2000-2004) > 1998, 1999.

From 2004 to the present, mucilage phenomenon didn't occur. In the period 1998-2013 seasonal and spatial distribution of the DOC content, and concentrations of the reactive part of organic matter with surface active (SA) properties³ have been studied. POC was examined from 2008. Seasonal distribution pattern of DOC and SAS over the whole investigated period clearly shows that after mucilage events of very high intensity (summer 1997) maximum values of DOC and SAS in 1998, and decreasing trend until 2006, in particular after 2000 were recorded. In the same period decrease in the Po River discharge and in phytoplankton biomass was observed^{4,5}. We believe that reduced SAS content, together with the absence of significant DOC accumulation in the recent years could have an important role in disappearance of mucilage events, contributing to the improvement of the ecological status of NA ecosystem. However, an increasing trend of DOC and SAS concentrations in the period 2007-2011 may indicate a new cycle of the organic matter accumulation, which accompanied with other favourable conditions may lead to the same biogeochemical processes as found during 1997-2004.

At the same time recent results on the organic matter study (DOC, POC) of the coastal and transition part of the Adriatic Sea monitored during 2012-2013 indicate mostly oligotrophic characteristics of the seawater with negligible anthropogenic influence.

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Keywords: Adriatic Sea, Organic Matter, DOC, SAS, Global changes

Oral presentation

Organic carbon flux in the mesopelagic zone at Station Papa estimated from the ^{234}Th and ^{230}Th measurements in different particle size classes

Francois R., Y. Luo Y., Miller L. and Yelland D.

We have estimated organic carbon flux in the upper 1600 m of the water column at station PAPA in the North Pacific by measuring ^{234}Th , ^{230}Th and organic carbon (POC) in small (1 – 63 μm) and large (> 63 μm) particles collected with in-situ large volume pumps, and in “extra-large” (> 236 μm) particles collected with a multinet. POC/ ^{234}Th was similar for small and large particles and decreased sharply in the upper 200 m of the water column, while POC/ ^{230}Th was higher in small particles and decreased more gradually with depth. POC fluxes estimated from ^{234}Th deficit and POC/ ^{234}Th in the upper 200 m agree well with historical sediment trap fluxes measured at 200m and with POC fluxes estimated from ^{230}Th deficit and POC/ ^{230}Th of small particles. The latter also yields POC fluxes down to 1600 m which agree well with historical sediment trap fluxes measured at 1000 m. These results suggest that POC flux attenuation in the mesopelagic layer could be accurately estimated from the POC/ ^{230}Th ratio of fine particles. However, POC/Th in “extra-large” particles is two orders of magnitude higher, suggesting that a large fraction of the POC flux may be missed by the Th-based methods and sediment traps.

Keywords: carbon flux, mesopelagic zone

Oral presentation

Linked carbon and nitrogen cycling in the coastal Arctic, will organic carbon release from thawing permafrost impose bacterial nitrogen limitation?

Frischer, M.E., Tait Z.P., Baylor V.D., Sipler R.E., Roberts Q.N., Stubbins A. and Bronk D.A.

A predicted consequence of climate warming in the Arctic is the release of vast reserves of permafrost stored carbon-rich (C:N > 25) organic matter to the coastal ocean. If bioavailable, this material would provide a carbon subsidy to carbon-limited bacteria. However, because it is relatively nitrogen depleted, this material may simultaneously impose N-limitation and increase the competition between heterotrophic bacterioplankton and autotrophic plankton for limiting N resources. Increased competition between microbial auto- and heterotrophs may lead to decreased primary productivity and ultimately a reduction of productivity at higher trophic levels in coastal Arctic ecosystems. To investigate this hypothesis we explored the genetic and biogeochemical potential of bacterial communities in the Western Arctic to utilize inorganic nitrogen in association with the assimilation of permafrost organic carbon. Community DNA samples collected from surface waters during the spring, summer, and winter from the Chuckchi shelf (2010 – 2012) revealed the ubiquitous presence of bacterial assimilatory nitrate reductase (*nasA*) genes. Recovered *nasA* genes were dominated by sequences similar to those observed in the Eastern Arctic and surprisingly little genetic diversity at this loci was observed. Gene expression levels were near undetectable levels. In concert with these observations, a series of laboratory-scale bioassays were conducted demonstrating the bioavailability of Arctic permafrost derived organic matter and confirming that utilization of this material conferred nitrogen limitation that was largely met by the availability of NO₃. These results indicate that bacterial drawdown of dissolved inorganic nitrogen may reduce net primary production in the Arctic coastal ocean as the flux of permafrost stored organic carbon increases associated with a warming Arctic.

Keywords: Arctic, DOM, Permafrost, Nitrogen, Bacteria, *nasA*

Oral presentation

Microbial regulations of ocean carbon sink: perspectives and testable hypothesis

Jiao N.

Marine microorganisms are the major players in the global ocean carbon cycle. They are not only responding climate changes sensitively as reported currently, but were also drivers for reshaping the earth climate system in the history, which leave fingerprints in the geological records that are traceable using organic biomarkers and stable carbon isotopes. A newly proposed concept, the microbial carbon pump (MCP) not only supplementary to the classical biological pump (BP) but also provides a framework to link the cross-disciplinary studies from genes to ecosystems and to combine current process study and ancient record for in-depth understanding of complex mechanisms behind the observed puzzling phenomena, such as, Why huge DOC reservoirs could hold under either anoxic or oxygenated environments in the earth history? Why oligotrophic ocean gyres hold large DOC reservoirs? Why nutrient-rich estuarine waters as well as productive upwelling areas are sources rather than sinks of CO₂? Our recent MCP studies in the western Pacific, for example, showed that excess nutrients could facilitate the uptake of DOC and enhance both bacterial respiration and bacterial production, the bacterial growth efficiency increased with increasing nitrogen concentration and then decreased again to certain extents depending on the field conditions, while the DOC left in the ambient water usually decreased with increasing nitrogen concentration, suggesting that excess nitrogen could simulate uptake of DOC in the environment and thus perform a negative effect on the preservation of DOC pool in the ocean. Therefore, the common sense that the more nutrients the more carbon fixation doesn't apply to carbon preservation in the ocean. To achieve maximum carbon sinks, both the biological pump and the microbial carbon pump should be taken into consideration for management in the coastal oceans where anthropogenic impacts such as eutrophication and hypoxia are severe. In the geological time scale, the MCP mediated ocean DOC reservoir could play a role of "acclimatization and feedback" in global climate change, which "fine-tunes" climate variation during the stable periods of geological time, "responds to and buffers" extreme climate events during unstable periods of geological time, and regulates the rejuvenation of new climate patterns after harsh geological incidents. Relevant hypothesis could be tested in the "ocean climate chamber" which will be introduced in the talk.

Keywords: microbial carbon pump

Oral presentation

Microbial formation of marine dissolved organic matter: recalcitrant or labile?

Kattner G. and Koch B.P.

Dissolved organic matter (DOM) in the ocean is composed of a small portion of labile compounds, but the main part is refractory or recalcitrant and thus not remineralized to CO₂ for thousands of years. To understand the cycling of marine DOM, a mechanistic understanding of its transformation processes is crucial but so far largely unexplored. Ultra high resolution Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR MS) enables to determine the molecular elemental composition of thousands of DOM molecules. Based on this technique, we tested the hypothesis that the microbial degradation of different substrates leads to non-labile DOM with similar molecular fingerprints. In our experiments we studied the changes in DOM concentrations and shifts in its molecular composition during the microbial utilization of glucose and an algal exudate over a period of two years. Although glucose was quickly degraded, a non-labile DOM background was generated which was dependent on the substrate concentrations: higher substrate levels resulted in a higher amount of background DOM. In contrast, only 20% of the organic carbon in the algal exudate was degraded within the two years of incubation. The molecular signatures of DOM derived from algal exudates or glucose after 70 days of incubation differed considerably from refractory DOM. After two years, however, the molecular patterns of DOM in the glucose incubations were very similar to refractory DOM whereas the degraded exudate was still strongly different.

We conclude that the amount and composition of non-labile DOM is dependent on concentration and composition of the initial substrate which is an important result with regard to carbon sequestration in the ocean. It must be considered, however, that two years of incubation are far away from the average DOC age of several thousand years in the deep ocean. Therefore, the material potentially could be further degraded and transformed by prolonged incubation, other microbial communities, or photo-degradation.

Keywords: Organic matter, microbial experiments, molecular fingerprints

Oral presentation

Significance of the microbial carbon pump in the globally changing ocean

Legendre L., Rivkin R.B., Weinbauer M., Guidi L. and Uitz J.

The microbial carbon pump (MCP), which was initially proposed in 2010, progressively transforms short-lived dissolved organic carbon (DOC) into long-lived compounds (lifetimes ≥ 100 years, i.e. semi-refractory and refractory DOC) by water-column microbial processes. The three vertical ocean carbon pumps described 30 years ago, i.e. the solubility, carbonate, and soft-tissue (or biological, BCP) carbon pumps maintain the gradient in Total CO₂ between surface and deep waters. Similarly, the MCP maintains the DOC gradient between shorter- and longer-lived DOC. Because the BCP and the MCP both sequester carbon (the BCP in deep waters, and the MCP at any depth as long-lived DOC), they both have biogeochemical and climate relevance. In the present study, we reformulate the MCP concept in biogeochemical terms, and use the reformulated MCP concept to explore the potential contributions of that carbon pump to the present and future responses of biogeochemical carbon fluxes to the globally changing ocean.

Keywords: Microbial carbon pump, long-lived DOC, biogeochemistry

Oral presentation

Probing microbial carbon pump in ancient oceans

Li C., Luo G., Huang J., Li L., Zhang Z., Shi W.

The microbial carbon pump (MCP) exists not only in today's oceans, but also existed in ancient oceans. There are many geochemical records which can be mechanically traced or connected to effects of a large recalcitrant dissolved organic carbon (RDOC) reservoir or intensive MCP processes in the Proterozoic (2.5-0.541Ga) oceans in which metazoans have not well evolved. These records include: (1) generally ^{13}C -enriched n-alkanes relative to coexisting isoprenoids (Logan et al., 1995), which can be well explained by MCP-related intensive heterotrophic degradation of primary n-alkyl lipids and subsequent addition of secondary ^{13}C -rich counterparts in the Proterozoic sediments; (2) the most ^{34}S -enriched pyrites (Li et al., 2012) and (3) the largest negative C-isotopic excursion (Grotzinger and Fike, 2011) in the Earth history, which all appeared in the Neoproterozoic sediments associated with global glaciations. Both anomalies can be well attributed to the eventual oxidation of the large RDOC pool generated possibly only by the MCP in the Neoproterozoic oceans; the former operated in the glacial deep oceans while the latter operated on non-glacial anoxic shelves. The development of this large RDOC reservoir was actually accompanied not only by the global cooling-warming alteration, but also by the eukaryotic radiation culminating in birth of the earliest animals on Earth. These coincidences imply that there must be some biogeochemical links behind them which needs us to explore in future.

Similar to those in the Neoproterozoic, the global oceans since last glacial maximum (~18ka) underwent cooling-warming alteration which was accompanied by an increase of >5 oC in temperature (Li et al., 2009) and ~100ppmV in pCO_2 (Monnin et al., 2001). It was very likely that the efficiency of the MCP, in turn the size of associated marine RDOC reservoir could have varied significantly along with the huge environmental changes. Unlike the Neoproterozoic sediments, biological lipids were well preserved in the young marine sediments due to the low thermal maturity. Thus theoretically we can track the MCP by looking at the relative variations of carbon and hydrogen isotopic compositions of n-alkyl lipids over the past 18ka because differential MCP would cause differential heterotrophic degradation of primary n-alkyl lipids and in turn differential addition of isotopically heavier secondary counterparts into the sedimentary pool. By comparing to other biogeochemical factors, we can further study the biogeochemical controls on the MCP and its ecological effects. In any case, our understanding of the MCP dynamics in the ancient times would be of great importance for prediction of the future variation trend under global changes.

Keywords: MCP, RDOC, Proterozoic oceans, last glaciation

Poster presentation

Timing the formation of the large DOC reservoir in the Ediacaran oceans

Luo G., Li C., Huang J., Zhang Z. and Zhang H.

The decoupled variations of $d^{13}\text{C}_{\text{carb}}$ and $d^{13}\text{C}_{\text{org}}$ in the Ediacaran strata characterized by large negative shift in $d^{13}\text{C}_{\text{carb}}$ (>10‰) with constant $d^{13}\text{C}_{\text{org}}$ have been ascribed to large dissolved organic carbon (DOC) reservoirs in oceans which, when oxidized, offered ^{13}C -depleted CO_2 for both the carbonate formation and organic production resulting in the strong negative shifts in inorganic C-isotopic records, but not in organic records due to the buffering effects of the large DOC reservoirs. However this hypothesis was challenged by recent studies which argued that the decoupled variation of $d^{13}\text{C}_{\text{carb}}$ and $d^{13}\text{C}_{\text{org}}$ was caused by detrital organic matter that affected the variation pattern of $d^{13}\text{C}_{\text{org}}$. Here we analyzed paired $d^{13}\text{C}_{\text{carb}}$ and $d^{13}\text{C}_{\text{org}}$ from the Ediacaran Doushantuo Formation, a strata sequence located in Siduping town, Hunan province, South China, which was deposited in a slope environment in order to test whether there was a large DOC reservoir in the Ediacaran oceans and, if so, when did this large DOC reservoir form.

The paired $d^{13}\text{C}_{\text{carb}}$ and $d^{13}\text{C}_{\text{org}}$ in the first 40m of the sequence show coupled variation ($R^2=0.67$), indicating that the large DOC reservoir has not been formed yet in this interval. This was also supported by relative large variability in $d^{13}\text{C}_{\text{org}}$. Meanwhile, it is interesting to note that the slope of the regression line between $d^{13}\text{C}_{\text{carb}}$ and $d^{13}\text{C}_{\text{org}}$ is ~ 1 , suggesting that the organic matter in this section was dominated by marine fraction and the detrital organic matter was too low to affect the values of $d^{13}\text{C}_{\text{org}}$. For the 40-120m of the sequence, the paired $d^{13}\text{C}_{\text{carb}}$ and $d^{13}\text{C}_{\text{org}}$ show decoupled variation ($R^2=0$) and $d^{13}\text{C}_{\text{org}}$ was very constant. We suggest that these features were induced by large DOC reservoir as we argued above and detrital organic matter was also very low at this section.

In summary, our paired $d^{13}\text{C}_{\text{carb}}$ and $d^{13}\text{C}_{\text{org}}$ records from the Ediacaran Doushantuo Formation at Siduping support the hypothesis that there was a large DOC reservoir in the Ediacaran ocean and this large DOC reservoir was formed a long time after the termination of the Marinoan glaciation. The future work is to uncover the biogeochemical factors which may have controlled the efficiency of the microbial carbon pump, in turn the size of the DOC reservoir in the Ediacaran oceans.

Keywords: DOC, MCP, Ediacaran oceans, Doushantuo Formation

Oral presentation

The major constraint for total DOM remineralization in the dark ocean: Quality, quantity or diversity of organic matter?

Marrasé C., Aparicio Bernat F.L., Borrull E., Romero E., Nieto Cid M., Gasol J.M., Sala M.M. and Ríos A.F.

A key aspect of the Microbial Carbon Pump (MCP) concept is the incomplete remineralization of Dissolved Organic Carbon (DOC) that occurs to a higher or lower degree in different ocean conditions. In the deep ocean, DOC is found in low concentrations. It is, furthermore, depleted in ^{14}C , indicating that the carbon compounds are circulating in time scales of multi-millennia, that is, several times the circulation time of the ocean. We performed several degradation experiments with deep water (4500 m) of the Atlantic Ocean to explore the priming effects of different mixtures of labile or recalcitrant organic carbon, simulating surface ocean inputs. The water was filtered through a $0.6\ \mu\text{m}$ pore size filter and distributed in four 20 L fluorinated polyethylene carboys. One of them, K, was kept as a control and the other 3 received additions of a mixture of carbon compounds that differed in biolability and chemical diversity. CL carboys received labile compounds (acetate and glucose). CM carboys received a mixture of eighteen organic compounds of different lability and CR received a mixture of humic acids as examples of recalcitrant compounds. Water from each of the experimental conditions was distributed among 24 acid cleaned glass bottles and incubated during 55 days. Three glass bottles for each condition were sampled at each sampling day of the experiment in order to follow the changes of the chemical and biological variables. Prokaryotic biomass increased when biolabile compounds or a diverse chemical mixture of molecules were added (CL and CM conditions), while no changes were observed in control conditions (K) or where recalcitrant organic matter was added (CR conditions). Interestingly, bacteria responded faster in the CM than in the CL conditions but biomass attained higher values in the CL conditions. Our results indicate that quantity and quality as well as chemical diversity of the organic matter are key factors determining bacterial activity in the deep ocean.

Keywords: Microbial Carbon Pump, DOC remineralization

Oral presentation

Link between microbial diversity and productivity in a mosaic of phytoplankton blooms

Landa M., Blain S., Christaki U., Monchy S. and Obernosterer I.

Heterotrophic bacterioplankton transform a large fraction of organic matter produced by photosynthesis, and thereby play a pivotal role in the marine carbon cycle. Despite the increasing knowledge on the structure and composition of bacterial communities in the ocean, the relationship between bacterial diversity and productivity is unresolved to date. Dissolved organic carbon concentrations in surface waters of the Southern Ocean are among the lowest in the global ocean, and any changes introduced to this pool of organic matter will have important implications for bacterial heterotrophic metabolism and diversity. Here we investigate bacterial responses to a patchwork of phytoplankton blooms induced by large-scale natural iron fertilization in the Southern Ocean (KEOPS2 project). The taxonomic composition of the response communities, determined by 454 pyrosequencing of the 16S rRNA gene, and the extent of change were highly variable among bloom sites. We used this spatial variability to demonstrate a strong link between bacterial productivity and the richness of the response community. To explain this relationship we provide in situ and experimental evidence for complementary traits of the enhanced taxa for both broad functions and the degradation of different organic matter sources. These results suggest resource partitioning to be an important driver for the composition of the response community. Our observations from a natural laboratory in the Southern Ocean provide evidence that species rich communities are more productive and that diversity sustains bacterially-driven ecosystem processes in response to changes in the ocean.

Keywords: bacteria, diversity, DOM, Southern Ocean, iron

Oral presentation

Growth, production and microzooplankton grazing on heterotrophic bacteria during different phases of a *Phaeocystis pouchetii* bloom

Pree B., Larsen A., Thingstad T.F., Nejstgaard J., Stoecker D., Simonelli P.

The carbohydrate-rich mucus from senescent blooms of the colony-forming haptophyte *Phaeocystis pouchetii* represents a massive input of C-rich organic matter to the planktonic food web. To what extent this material is degraded within in the microbial loop web or transported up the food chain is not well understood.

A research cruise in spring 2013 to Barents Sea was aiming to investigate the fate of *P. pouchetii* colonies during an early and a later phase of the bloom found in the inner and outer part of the Porsangerfjord, respectively. To determine the impact of grazing of nano- and microzooplankton on bacteria, dilution experiments were employed at these two stations. Production, growth rates and grazing mortality of heterotrophic bacteria were assessed.

In the early phase of the *Phaeocystis* bloom, bacterial concentration at Chl a maximum (20m) was 10.3×10^5 cells ml⁻¹, and bacterivory of 0.14 d⁻¹. Heterotrophic nanoflagellates and microzooplankton consumed only 13% d⁻¹ of the standing stock of *P. pouchetii* when the bloom is young. In the late phase of the bloom bacterial concentration is significantly lower (2.8×10^5 cells ml⁻¹) than during the young phase, whereas bacterivory rate was higher (0.44 d⁻¹) with grazing responsible for removal of 36% of the standing stock of bacteria d⁻¹. Production per bacterial cell was high and cells were big in size in the diluted water samples at the end of the dilution experiment. This could be due to release of organic nutrients during handling of water for grazing experiments when *P. pouchetii* colonies are old, or by a dilution of inhibitory substances from those colonies.

Our findings show that bacteria are more abundant in the early phase of the bloom and that bacterivory has a greater impact during the late phase of the bloom. The fact that bacteria increased in size in the diluted water is puzzling and needs further investigation. Heterotrophic bacteria and the microbial food web are responding to different phases of *P. pouchetii* bloom, with implications for carbon dynamics and trophic structure.

Keywords: Phaeocystis, microzooplankton grazing, bacteria, bacterial production

Oral presentation

Why does dissolved organic matter persist in the deep ocean? Is part of the solution, dilution?

Stedmon C.A., Jørgensen L. and Traving S.J.

Dissolved organic matter (DOM) is found in all natural waters and has been accumulating to some extent since the start of life on Earth. These compounds represent “life’s leftovers”: the residue remaining at the end of the abiotic and biotic degradation continuum. The vast majority of organic carbon in the ocean is dissolved (>95%) and persists as refractory DOM – apparently resisting microbial utilization. Our calculations reveal that this in part can be explained by a combination of extreme dilute concentrations of individual organic compounds and the vast diversity of compounds present in DOM. Encounter rates between substrates and microbial cells are so low that it is likely that compounds persist at concentration below the threshold for viable utilization.

Keywords: dissolved organic matter, carbon, refractory

Oral presentation

Unravelling carbon fixation under nutrient limited conditions - a water column perspective

Thomas H., Craig S., Shadwick E.H., Li W.K. and Greenan B.J.W.

Phytoplankton plays a critical role in the uptake of atmospheric carbon dioxide (CO₂) by the ocean, and is comprised of a spectrum of cell sizes that are strongly regulated by oceanographic conditions. Elevated CO₂ fixation relative to nutrient availability, also called carbon overconsumption, has been observed in various mid to high latitude systems, such as the Baltic and North Seas, the North Atlantic Ocean, the Canadian Arctic Archipelago or the Scotian Shelf. We shed light on this phenomenon relying on an extensive data set of water column observations of the CO₂ system and phytoplankton cell counts from the Scotian Shelf, a temperate shelf sea. We show that in the summertime, the population of numerically abundant small cells, which favour warmer, nutrient poor conditions, accounts for approximately 20% of annual carbon uptake. At the broader scale, the neglect of this “non-Redfieldian” contribution typically leads to an underestimation of net community production by approximately 20% to 50%. These small cells are not well represented by chlorophyll a – the ubiquitously used proxy of phytoplankton biomass – but rather, are strongly correlated with surface water temperature. Given the persistent near-zero nutrient concentrations during the summer, it appears that small cells drive carbon overconsumption, and suggest that their role in carbon fixation will become increasingly important in a warming, increasingly stratified ocean.

Keywords: CO₂, community structure, nutrient limitation

Poster presentation

Rapid degradation of particulate and dissolved organic matter in a naturally iron-fertilized region of the Southern Ocean

Tremblay L., Caparros J., Leblanc K. and Obernosterer I.

The Southern Ocean contains the largest high-nutrient low chlorophyll (HNLC) area of the world. However, natural iron fertilization events produce important phytoplankton blooms in spring. Little is known on the fate of the organic matter produced during these blooms, especially for the dissolved fraction. The objective of this work was to evaluate the origin and fate of the particulate and dissolved organic matter (POM and DOM) in regions of the Southern Ocean exhibiting contrasting conditions. To do so, bulk and amino acid (D/L-AA) analyses were done on unfiltered and filtered water samples from iron induced bloom and HNLC sites. D/L-AA are among the few molecular markers that can be analyzed in bulk seawater and provide numerous indicators of organic matter origin and fate.

Different approaches indicated that POM mostly originated from diatoms and bacteria. The contribution from intact cells was lower at the HNLC site. The POM from deep waters appeared to be mostly made of detritus of various origins. AA accounted for 10% (HNLC) to 25% (bloom) of particulate organic carbon in surface waters and for 3 – 5% in deep waters. Estimates based on D-AA yields indicated that 17 to 35% of bulk DOM was of bacterial origin in all the studied samples. AA accounted for 0.9% (bloom) to 2.7% (HNLC) of dissolved organic carbon.

The blooms produced large quantities of POM and DOM that are more rapidly altered or mineralized compared to the organic matter from the HNLC-site. Three different markers indicated that the most productive bloom station was characterized by a marked and steady increase of DOM degradation state with depth. Such a trend was not observed for the DOM in the HNLC region. These contrasting results can be caused by a difference in the DOM (substrate) degradability and/or a difference in microbial (consumer) living conditions. These two causes can be linked considering that labile DOM represents a source of vital elements and energy that promote microbial activity. The labile DOM (e.g., free AA) produced during the bloom probably induces a strong microbial response that stimulates the degradation of more DOM, including semi-labile molecules. Most of the bloom DOM appears to be recycled too fast to accumulate. Moreover, a limitation in iron in the HNLC region may also reduce microbial activity and thus the rate of DOM degradation compared to the bloom area. Unfavourable conditions for heterotrophic bacteria in the less productive regions (e.g., HNLC) can explain the slightly higher dissolved AA concentrations, mostly combined (e.g., peptides), measured in their surface waters. Insufficient labile carbon and/or iron quantities in HNLC region probably reduce the degradation rate of these relatively labile molecules.

This study shows for the first time the contrasting dynamics of the DOM produced in the surface water during natural iron fertilization and from a HNLC region. Our results suggest that iron induced blooms produce POM and DOM that are rapidly degraded with important implications for the carbon budget and export in the Southern Ocean.

Keywords: Organic matter, iron-fertilization, Southern Ocean

Oral presentation

Comparative genome analysis of three marine roseophages, new insights into the link of genes and environment

Xu Y., Zhang R., Chen F., Jiao N.,

RDJL ϕ 1 was the first phage isolated from *Roseobacter denitrificans* OCh114. In this study, three more siphophages RDCB ϕ 1, RDCB ϕ 2, RDCB ϕ 3 were isolated from an estuarine environment of different seasons, and characterized from the aspect of morphology and genome sequence. RDCB ϕ 1, RDCB ϕ 2 and RDCB ϕ 3 were isolated from the Baltimore Inner harbor seawater of winter, spring and summer, respectively. RDCB ϕ 1 is morphologically and genomically similar to RDJL ϕ 1. The genome length and G+C content of RDCB ϕ 1 are both higher than those of RDJL ϕ 1. 91 ORFs was predicted from the RDCB ϕ 1 genome, 71 ORFs are homologous to those of RDJL ϕ 1. RDCB ϕ 2 and RDCB ϕ 3 are closely related to each other with respect to elongated capsids, similar genome size and G+C content. RDCB ϕ 2 and RDCB ϕ 3 share 50 ORF homologs. Many of the ORFs are related to those identified from *Pseudomonas* phage M6, M1412, and YuA. RDCB ϕ 1, RDCB ϕ 2 and RDCB ϕ 3 all contain integrase genes which indicates they may be capable to integrate into the host genome. The existence of MazG-like protein NTP-PPase in the three phage genomes represents the genomic adaption to the nutrient-limited environment. Furthermore, the NTP-PPase of RDCB ϕ 1 can help organisms to adapt to cold environments, which is homologue to the winter season when RDCB ϕ 1 was isolated. In addition, RDCB ϕ 2 and RDCB ϕ 3 have a DNA repair photolyase, which could coordinate the infection to the elongated daytime of the spring and summer. Similar to RDJL ϕ 1, four RCGTA-like genes gp12-gp15 were also found in RDCB ϕ 1, RDCB ϕ 2 and RDCB ϕ 3 genome. Phylogenetic analysis of the four-concatenated genes showed these four phage strains clustered into the same lineage. The comparative genome sequence analysis provides us new insights into the link of genes and environment.

Keywords: roseophage, genome, RCGTA-like genes, adaption

Poster presentation

The effect of phage infection on cyanobacterial central carbon metabolism

Zeng Q.

The closely related unicellular cyanobacteria *Prochlorococcus* and *Synechococcus* are the most abundant photosynthetic cells in the oceans and are thought to be responsible for 50% of the total primary production in oligotrophic regions of the oceans. *Prochlorococcus* and *Synechococcus* are actively infected by lytic bacteriophages (cyanophages) which are the most abundant viruses in the oceans, however the molecular mechanism of how their primary production is affected by cyanophage infection is still not clear. Cyanophages contain host-like metabolic genes involved in photosynthesis, photosynthetic electron transfer, pigment synthesis and pentose phosphate pathway. Cyanophages don't contain any Calvin cycle gene. Instead, many of them carry a Calvin cycle inhibitor gene *cp12*, which is used by cyanobacteria and plants to shut off the Calvin cycle at night. In cyanobacteria, the Calvin cycle uses NADPH and ATP produced in the light reactions of photosynthesis for carbon fixation during the day. At night, the pentose phosphate pathway does the reverse and oxidizes glucose 6-phosphate produced in the Calvin cycle to generate NADPH and ribose 5-phosphate. With supporting evidence, we hypothesized that the host-like genes that have been acquired by cyanophages serve to enhance the synthesis of NADPH, ATP and ribose 5-phosphate, inhibit their utilization for carbon fixation in the host, and redirect their use to power nucleotide biosynthesis that is critical for phage reproduction. We further test our hypothesis by directly studying the host central carbon metabolism after phage infection from different aspects: gene expression, protein interaction and metabolite level.

Keywords: cyanobacterium, bacteriophage, photosynthesis, Calvin cycle

Oral presentation

DOC dynamics and CDOM fluorescence in the interconnected Marmara - North Aegean Seas

Zeri C., Besiktepe S., Giannakourou A., Pitta E., Tzortziou M. and Mouzdis G.

The dynamics of dissolved organic carbon (DOC) in the Marmara Sea- Dardanelles Straits – North Aegean Sea were investigated, by combining measurements of DOC ($\mu\text{mol/L}$) with 3-D fluorescence excitation-emission spectra (EEMs) and bacterial production (BP) ($\text{nmol C L}^{-1} \text{d}^{-1}$) and respiration (BR) ($\text{nmol CL}^{-1}\text{d}^{-1}$) rates. This is the area where low salinity and rich in terrigenous and marine DOM waters, originating from the Black Sea, mix with the oligotrophic waters of eastern Mediterranean Sea. A specific flow regime with two counterflowing water bodies is formed. The longitudinal distribution of DOC concentrations in the surface brackish waters showed a more than 2-fold decrease from the Marmara Sea to the N. Aegean ($65\text{-}217 \mu\text{molL}^{-1}$) followed by a decrease in BP rates ($7.2\text{-}195 \text{nmolL}^{-1}\text{d}^{-1}$). BR was 10 times lower in the N. Aegean ($110 \text{nmol CL}^{-1}\text{d}^{-1}$) than in the Marmara Sea ($2340 \text{nmol CL}^{-1}\text{d}^{-1} - 1170 \text{nmol CL}^{-1}\text{d}^{-1}$). Bacterial carbon demand (BCD) in the Marmara Sea was $1880 \text{nmolCL}^{-1}\text{d}^{-1}$. This is the amount of labile and semilabile DOC needed to sustain the bacterial communities there. Significantly lower BP and BR rates measured in the N. Aegean result in an average $\text{BCD} = 120 \text{nmolC L}^{-1}\text{d}^{-1}$. In the low salinity surface waters of the Marmara Sea, intense biodegradation processes take place resulting in the high BP rates observed and in the consumption of the majority of labile and semilabile DOC fractions. DOC concentrations in the subsurface waters did not show significant variation from the N. Aegean (to the Marmara sea $62\pm 4 \mu\text{molL}^{-1}$), while an increase in BP rates ($3.3 - 17.4 \text{nmolL}^{-1}\text{d}^{-1}$) was recorded. Lack of significant correlation of DOC vs AOU in the deep Marmara basins indicates that the specific hydrological structure of the Marmara Sea blocks any significant vertical export of DOM, and deep mineralization processes are mostly dependent on particulate organic matter which sustain the relatively increased BP rates. PARAFAC modelling of EEMs revealed three fluorescent components: [C1] $\lambda_{\text{ex}}/\lambda_{\text{em}}$: $<260(330)/464 \text{nm}$, humic-like; [C2] $\lambda_{\text{ex}}/\lambda_{\text{em}}$: $<(260) 285/364 \text{nm}$, quinone-like; [C3] $\lambda_{\text{ex}}/\lambda_{\text{em}}$: $270/308 \text{nm}$, tyrosine-like corresponding to terrigenous humic-like components and of peptide degradation products. The regression of DOC vs FTOT reveals that in the surface brackish waters DOM is highly fluorescent and only $31 \mu\text{molL}^{-1}$ DOC correspond to non-fluorescent DOM. C2 showed strong covariance with humic component C1 ($r=0.95$, $p=0.000$, $n=14$), suggesting that C2 may be associated with bacterioplankton growth (bacterial alterations of humic precursor material). The observed increase of C3 in the Aegean waters implies that the tyrosine-like fluorescent component is not only transported from the Marmara Sea to the N. Aegean but is also produced in situ in the N. Aegean Sea and is of recalcitrant nature. The present study provides information on DOM biogeochemistry in the Marmara Sea and in the mixing zone of BSW with LIW in the N. Aegean Sea. Results from this work have important implications for the role of the Dardanelles outflow on the carbon cycle and the ecosystem functioning in the eastern Mediterranean Sea.

Keywords: DOC, CDOM, bacterial production, PARAFAC, Mediterranean

Poster presentation

Change in community structure of planktonic Archaea from the lower Pearl River to the Northern South China Sea: Implications for archaeal ecological functions in different habitats

Xie W. and Zhang C.

Archaea are widespread and play an important role in the global carbon and nitrogen cycles. However, we still have limited knowledge about how the function of Archaea changes in varying habitats. The current paradigm is that change in community structure causes change in community function. Thus the goal of this study was to examine the change in community structure of planktonic Archaea from the Pearl River to the northern slope of the South China Sea (SCS) in order to evaluate how archaeal ecological function changes along the salinity gradient. Pyrosequencing of the 16S rRNA gene of Archaea was performed on samples that had salinity ranging from 0.0 in the river water to >3.0‰ in the open ocean. The results showed that methanomicrobiales and miscellaneous Crenarchaeotal group were abundant in the lower Pearl River, Nitrosopumilus-like species were abundant in estuary and shallow seawater, and Marine group II and III were abundant in deep seawater of the North South China Sea. Methanomicrobiales are known methane-producing organisms and Nitrosopumilus is known to oxidize ammonia and fix CO₂. Thus, the archaeal community appears to be able to perform methanogenesis in the freshwater and nitrification in the estuary and shallow sea with unknown function in the deep seawater. Furthermore, a metagenomic investigation of the plankton from Pearl River to the northern slope of SCS showed that the abundances of genes involved in 3-HP and reductive acetyl-CoA CO₂ fixation increased with salinity, indicating that these pathways may become more important from Pearl River to SCS. A detailed bioinformatic analysis is underway to evaluate the relative contributions of Archaea and Bacteria in the carbon metabolic processes in these settings.

Keywords: Archaea, Pearl River, metagenome

Oral presentation

Production of exopolysaccharide by marine bacteria

Zhang Z., Chen Y. and Jiao N.

Exopolysaccharide (EPS) is one of major constituents of marine dissolved organic carbon (DOC). EPS can be produced by many microbes such as microalgae and bacteria. EPS producing bacteria have been isolated from various marine environments, particularly extreme marine environments such as hydrothermal vents, deep sea water and hypersaline marine environment. In this study, we investigated the EPS producing bacteria from South China Sea and west Pacific Ocean. Sea water from surface to deep sea was collected. EPS-producing bacteria were isolated and identified based on 16S rRNA analysis. The result shown that the predominant culturable EPS-producing bacteria are belong to the genera *Alteromonas* of Gammaproteobacteria. The production of EPS produced by marine bacteria and the contribution of EPS on the DOC was also analyzed. The result suggested that bacterial EPS is one of relative refractory DOC.

Keywords: exopolysaccharide, bacteria, *Alteromonas*, DOC

Poster presentation

Session B3: The pivotal role of the mesopelagic functional groups in biogeochemical cycles

Oral Presentations

Wednesday 25 June, 14:00-15:30 Parallel session 5

Room D8

Time	Presenter	Title
14:00-14:20	Aksnes, Dag L	Light dependent behavior of the mesopelagic sound scattering layer across the Norwegian Sea.
14:20-14:40	Irigoiien, Xabier	Large Mesopelagic Fish Biomass and Trophic Efficiency in the Open Ocean
14:40-15:00	Peterson, Sarah	Mesopelagic foraging influences mercury accumulation in elephant seals from the North Pacific
15:00-15:20	Costa, Daniel	Revealing the diet of the northern elephant seal: Insights into a mesopelagic food web
15:20-15:30	All	Discussion

Session B3: Mesopelagic functional groups – Abstracts

Light dependent behaviour of the mesopelagic sound scattering layer across the Norwegian Sea.

Norheim E. and Aksnes D.L.

The mesopelagic sound scattering layer (MSSL) is characterized by extensive vertical migration and this migration is likely the largest biomass transport on earth. A common referred hypothesis for this phenomenon is that the organisms of the MSSL swim to large depths in daytime to hide for visual predators and return to the surface at night to feed. Here migration represents a transport leg between two habitats, the surface habitat for feeding (at night) and the deep habitat to hide (at daytime). At high latitudes in summer, however, the clear distinction between day and night disappears. Under these circumstances, we investigate the MSSL migration pattern across the Norwegian Sea. We find that the traditional notion of day and night, and the two associated habitats, is of little relevance for the observed migration pattern. The MSSL continuously adjust its depth location according to the changes in the incoming solar irradiance suggesting that the underlying behaviour is governed by the preference for a certain range in light intensity regardless the time of day. This is similar to the behaviour previously described for mesopelagic fishes in fjords. Our observations are consistent with the “antipredation window hypothesis” where migration is assumed to extend the period for safe feeding rather than being a transport between two distinct habitats.

Keywords: mesopelagic fish, migration, light

Oral presentation

Revealing the diet of the northern elephant seal: Insights into a mesopelagic food web

Goetsch C., Connors M., Mitani Y., Walker W., Simmons S.E., Reichmuth C., Budge S. and Costa D.P.

A fundamental component of the foraging ecology of any predator is knowledge of their diet. Determining the diet of mesopelagic predators is particularly challenging and, after more than 30 years of study, the diet of northern elephant seals (*Mirounga angustirostris*) remains largely unknown. To determine a more representative diet for northern elephant seals, we compared the fatty acid composition of blubber with mesopelagic prey collected in their foraging habitat using quantitative fatty acid signature analysis (QFASA). We collected blubber biopsies from adult seals upon return from a foraging migration (females: 2005-2006 n = 58, 2009-2012 n = 119; males: 2010-2011 n = 13). In summer 2012, we collected 56 species of potential prey (12 species of mesopelagic squid and 44 species of deep sea fish) from the North Pacific Transition Zone, using net trawls deployed from 650 to 800 m, where elephant seals typically forage. Blubber and prey samples were processed for fatty acid methyl esters and analyzed via gas chromatography to obtain a fatty acid profile for each seal and all prey species. We used the QFASA statistical model to determine the diet for each elephant seal, revealing evidence of individual diet specialization with some seals focusing on squid and others on mesopelagic fish. Contrary to previous studies, we found that mesopelagic fish comprise a substantial proportion of the diet for both males and females (on average 50% fish and 50% squid for both). Hierarchical cluster analysis on the prey fatty acid profiles showed distinct groupings that may be indicative of predator-prey relationships among the nektonic species of the deep scattering layer. Finally, we found that the fatty acid signatures for seals foraging during the 2009-2010 El Niño were significantly different than seals foraging in 2011 and 2012 (Permanova, $p=0.001$), suggesting a diet switch in response to changes in El Niño state. The diet switch may be indicative of changes in the abundance of nektonic species within the mesopelagic zone in response to changing environmental conditions.

Keywords: diet, predator, mesopelagic, food web, QFASA

Oral presentation

Large mesopelagic fish biomass and trophic efficiency in the Open Ocean

Irigoién X., Klevjer T.A., Røstad A., Martínez U., Boyra G., Acuña J.L., Bode A., Echevarría F., González-Gordillo J.I., Hernández León S., Agustí S., Aksnes D.L., Duarte C.M., Kaartvedt S.

With a current estimate of about 1000 million tons, mesopelagic fishes likely dominate the world total fishes biomass. However, recent acoustic observations show that mesopelagic fishes biomass could be significantly larger than the current estimate. Here we combine modelling and a sensitivity analysis of the acoustic observations from the Malaspina 2010 Circumnavigation Expedition to show that the previous estimate needs to be revised to at least one order of magnitude higher biomass. We show that there is a close relationship between the open ocean fishes biomass and primary production, and that the energy transfer efficiency from phytoplankton to mesopelagic fishes in the open ocean is higher than what is typically assumed. Our results indicate that the role of mesopelagic fishes in oceanic ecosystems and global ocean biogeochemical cycles needs to be revised as they may be respiring around 10 % of the primary production in deep waters.

Keywords: mesopelagic fish, acoustics, modelling, trophic efficiency

Poster presentation

Mesopelagic foraging influences mercury accumulation in elephant seals from the North Pacific

Peterson S., Ackerman J. and Costa D.

Northern elephant seals (*Mirounga angustirostris*) are mesopelagic (200-1000 m) marine predators that travel thousands of kilometers during their biannual migrations to forage in coastal and open-ocean regions of the North Pacific Ocean. As upper-trophic level predators, elephant seals bioaccumulate mercury, and may be good indicators of regional contamination, especially because individual seals demonstrate strong regional fidelity. Regional differences in mercury within surface-feeding oceanic animals have been observed in the North Pacific, but less is known about geographic mercury distribution within deeper, mesopelagic food webs of the North Pacific. Although little is known about mercury in mesopelagic predators, we know that mercury is more bioavailable in this zone due to marine biogeochemistry. Blood and muscle were sampled from adult females and males during 2010-2013 and analyzed for total mercury. For adult females, we used satellite tags and time-depth recorders to examine how mercury varied by age and at-sea foraging behaviors. Mercury concentrations in female blood samples (N=75) upon arrival to the breeding colony ranged from 180-648 ng/g ww and males (N=32) ranged from 221-1062 ng/g ww. These concentrations fall at the higher end of blood mercury concentrations reported for marine mammals or seabirds. Moreover, foraging ecology influenced mercury concentrations in adult female elephant seals, both in two and three dimensions. Mercury concentrations were greatest in females that foraged the deepest during the day. Additionally, females that foraged further offshore had higher concentrations than females that foraged closer to the coast. This is the first study that uses non-lethal sampling to pair tissue total mercury concentrations with the foraging ecology of healthy (non-stranded), deep-diving marine mammals from the North Pacific. Our results provide insight into the interactions between foraging ecology and total mercury accumulation in a top marine predator as well as how mercury may vary across the North Pacific mesopelagic. Our results indicate that mesopelagic marine predators may be at greater risk for mercury accumulation than previously assumed and provide insight into the potential for mercury bioaccumulation in more elusive and vulnerable species.

Keywords: Mercury, bioaccumulation, mesopelagic predator, Pacific

Oral presentation

Session B4: Ocean biogeochemical dynamics under changing climate: feedbacks and impacts

Oral presentations

Wednesday 25 June 16:00-17:30 Parallel session 6

Chair: Christoph Heinze

Room D8

Time	Presenter	Title
16:00-16:20	Gehlen, Marion	Future pH Reductions put North Atlantic Deep-Sea Ecosystems at Risk
16:20-16:40	Stoll, Heather	Stimulation or limitation of phytoplankton biomineralization under rising CO ₂ ?
16:40-17:00	Bach, Lennart	The influence of ocean acidification on particle sinking velocity dynamics in a natural plankton community
17:00-17:20	Paul, Allannah	Insight into the Fate of Newly-Fixed Nitrogen in a High CO ₂ Ocean
17:20-17:30	All	General discussion

Thursday 26 June, 14:00-15:30 Parallel session 7

Chair: Are Olsen

Room D8

Time	Presenter	Title
14:00-14:20	Oschlies, Andreas	Unexpected increase in the simulated marine oxygen inventory in a warmer future ocean
14:20-14:40	Somes, Christopher	Estimating the influence of "non-Redfield" dissolved organic matter cycling on the global oceanic fixed nitrogen inventory in the modern and glacial oceans
14:40-15:00	Keller, Kathrin	Variability of the ocean carbon cycle in response to El Niño-Southern Oscillation: impact of the climatological mean state
15:00-15:20	Goris, Nadine	Quantifying the climate-driven processes leading to a reduced CO ₂ uptake in the North Atlantic: A model study with the Bergen Climate Model
15:20-15:30	All	General discussion

Session B4: Biogeochemical dynamics under changing climate

Friday 27 June, 10:30-12:00 Parallel session 8

Chair: Jerry Tjiputra

Room D8

Time	Presenter	Title
10:30-10:50	Jeansson, Emil	Anthropogenic CO ₂ penetration in the Greenland Sea over the last decades
10:50-11:10	Blain, Stéphane	Impact of large scale natural iron fertilization on carbon cycling in the Southern Ocean
11:10-11:30	Bratkič, Arne	Hg speciation in water column in South Atlantic Ocean along 40°S parallel
11:30-11:50	Sweetman, Andrew	Scavenging dynamics of jellyfish versus fish falls at the deep seafloor
11:50-12:00	All	General discussion

Poster Presentations

Wednesday 25 June, 17:30, Poster Session 2

ID	Presenter	Title
B4.P1	Belcher, Anna	Variability of carbon export and remineralisation in the Southern Ocean
B4.P2	Keller, Kathrin	Time of Emergence of trends in ocean biogeochemistry
B4.P3	Schwinger, Jörg	Different response of the natural and the anthropogenically disturbed ocean carbon cycle to changing climate
B4.P4	Alcaraz, Miquel	Global Warming, Zooplankton Shifts, and Biogenic Carbon Fate in the Southern Ocean
B4.P5	Morée, Anne	The role of the Southern Ocean in global carbon cycling
B4.P6	Ray, Raghav	Exchange dynamics and storage of nitrogen in a tropical mangrove ecosystem
B4.P7	Steele, Deborah	Cell Viability and Chlorophyll Alteration in Eukaryote Phytoplankton; A Seasonal Cycle in the Western English Channel
B4.P8	Li, Xuefeng	Response of diatom <i>Chaetoceros Socialis</i> to a changing climate and dust deposition: role of iron
B4.P9	King, Andrew	Effects of CO ₂ on phytoplankton-mediated micro- and macronutrient cycling

Global warming, zooplankton shifts and biogenic carbon fate in the Southern Ocean

Alcaraz M., Almeda R., Duarte C.M. and Horstkotte B.

The carbon metabolic demand estimated as carbon-specific respiration rates of mixed copepods, salps (*Salpa thompsoni*) and krill (*Euphausia superba*), were studied in a series of stations in the proximity of the Antarctic Peninsula in February 2009. Our objective was to determine the consequences for the cycling and vertical flux of biogenic carbon of the predicted individual biomass (IM) reduction due to temperature increase and the already occurring zooplankton shift from krill to salps.

The CR of zooplankton was inversely related to individual zooplankton carbon biomass, $CR=0.0294 \cdot IM^{-0.190}$ $r = 0.78$, and the average CR of salps 0.08 d^{-1} , higher by a factor of 5 than that of krill. While krill is fundamental in Antarctic food webs, salps play an indifferent trophic role. If salps substitute krill, the resulting zooplankton community, apart from having lower value as food, will demand higher amounts of carbon per unit biomass (CR), further enhanced by the IM reduction. The production of larger, heavier salps' faecal pellets will also increase the rate of biogenic carbon settling, thus modifying the carbon cycle in Antarctic ecosystems.

Keywords: Antarctica, Zooplankton, Community shifts, Carbon cycling

Poster presentation

The influence of ocean acidification on particle sinking velocity dynamics in a natural plankton community

Bach L.T., Boxhammer T., Sett S., Larsen A. and Riebesell U.

The sinking velocity of particulate organic matter is a key variable controlling the amount of photosynthetically fixed carbon that reaches the deep ocean. Sinking velocities depend on particle properties such as size and density. Both of these properties are determined by the organisms which produce them. Thus, particle sinking velocities and organic matter export are closely connected to the composition of the plankton community. Changes in sinking velocities due to environmental change are poorly constrained although this may seriously affect the efficiency of the biological pump. In May 2011, we measured sinking rates of particulate matter and food web dynamics on a daily basis in 9 KOSMOS mesocosms which were deployed in a Norwegian Fjord close to Bergen and subsequently enriched with different CO₂ concentrations to simulate ocean acidification. Particulate matter was collected in sediment traps at the bottom of the mesocosms (23 m depth). During the first two weeks of the experiment sinking velocities remained relatively constant in the large and fecal pellet-dominated size classes (~200-400 µm in equivalent spherical diameter) and consistently decreased in the smaller ones (80-200 µm) which were dominated by fluffy detritus. The CO₂ level had no influence on sinking rates during this initial phase. The different trends among both size classes is most likely due to a more pronounced reduction of density in the small fluffy material than in the compact fecal pellet material. A nutrient addition two weeks after the start of the experiment led to an abrupt decrease in sinking velocities of larger particles which may be due to the production of fresh and less dense material. The coccolithophore *Emiliana huxleyi* which is covered with calcareous scales formed moderate blooms (up to ~2700 cells/mL) in some of the low CO₂ mesocosms three weeks after the experiment started. The occurrence of this species and the associated increase in CaCO₃ particles accelerated sinking velocities profoundly with a clear linear correlation between *E. huxleyi* cell abundance and particle sinking velocities in all size classes. This correlation was used to assess the influence of a natural coccolithophore bloom on export fluxes. We estimate that the presence of *E. huxleyi* in some of the low CO₂ treatments increases the amount of particulate matter reaching 1500 m depth by a factor of three relative to the treatments (mainly high CO₂) where the abundance of this species remained low. These results show: (1) sinking velocities change over the course of a plankton bloom which should be taken into consideration in model parameterizations. (2) *E. huxleyi* can be considered a “biogeochemical marker species” which is indicative for relatively large export fluxes. (3) Lower abundance of *E. huxleyi* in an acidified ocean may reduce the amount of particulate matter that reaches the deep ocean.

Keywords: plankton sinking velocity export ocean acidification

Oral presentation

Variability of carbon export and remineralisation in the Southern Ocean

Belcher A.

Using satellite data to derive estimates of carbon export allows global assessment of parameters that cannot be easily measured at such high resolutions. Although several models exist that link sea surface temperature (SST) and primary productivity with export from the euphotic zone, recent analyses suggest that regional variations can be significant. Regions of low temperature such as the Southern Ocean, exhibit a negative trend of export efficiency with primary production and SST seems to play a less important role in export than suggested by global models. Not all of this exported particulate material actually makes it through the twilight zone and ultimately to the sea floor. For accurate knowledge of ocean carbon drawdown, it is essential to quantify the remineralisation rate of sinking material and understand the drivers of temporal and spatial variability. A relationship between Martin's b value and SST has been suggested based on limited data, which if correct would allow global estimates of carbon remineralisation from satellite SST observations. This in turn would enable the development of global climatologies of carbon export and better prediction of the oceanic response to a changing climate.

During a cruise to the Scotia Sea in austral summer 2014, Marine Snow Catchers were deployed at multiple depths to measure the changes in export both spatially and temporally. The study site of South Georgia provides a unique setting to investigate the controls on export and remineralisation processes in two contrasting regions (different ecosystem structure but of similar temperature). Initial data from the Scotia Sea cruise are presented and relationships between SST and Martin's b value explored to assess the validity of the use of SST as a proxy for export. Changes in particle size and composition are examined in relation to surface zooplankton populations to help understand the key controls on the temporal and spatial variability of particle export from the euphotic zone and remineralisation with depth.

Keywords: carbon export, southern ocean, marine snow catcher

Poster presentation

Impact of large scale natural iron fertilization on carbon cycling in the Southern Ocean

Blain S., Quéguiner B., Trull T., Armand L., Boutin J., Bowie A., Cavagna A.J., Carlotti F., Chever F., Christaki U., Closset F.Y., D'Ovidio F., Dehairs F., Fernandez C., Fourquez M., Jouandet M.P., Leblanc K., Lefèvre D., Lo Monaco C., Lauranteau E., Lasbleiz M., Obernosterer I., Park Y., Planchon F., Quéroué F., Sallé J.B., Sarthou G., van der Merwe P., van Beek P. and Zhou M.

The Southern Ocean plays a major role in the control of climate. In turn it is also very sensitive to climate variability and the impacts of the current climate change have already been detected. In the past, large scale natural iron fertilization of the Southern ocean, in combination with other processes, has contributed to important modifications of earth's climate. However, the detailed mechanisms driving the response of the biological pump of CO₂ to iron fertilization are still poorly understood. Previous field studies conducted in naturally iron fertilized regions or in artificially iron fertilized patches have led to controversial results (e.g. the efficiency of the fertilization on the carbon sink). Large differences exist also between the results of biogeochemical models and between models and field studies. The KEOPS (Kerguelen Ocean and Plateau compared Study) in combination with historical data in the Kerguelen region provide observations at temporal and spatial scales that have not been explored previously. The magnitude and the mechanisms supplying the surface waters with iron varied dramatically with the season and are closely linked to ocean circulation and dynamics. The variability of carbon export, driven by the structure and dynamics of the ecosystem, is also pronounced throughout the season. All together this leads to a large intra-seasonal variability of the efficiency of the fertilization. Such intrinsic variability of a fertilized system, may explain the previously observed discrepancies. Large scale iron fertilization of the Southern Ocean in the Kerguelen region results in a mosaic of blooms that allow studying the multiple responses of the ecosystem to natural fertilization. Moreover, thanks to a compilation of more than 1000 surface water pCO₂ measurements we are able to estimate the annual CO₂ sink due to iron fertilization. Large scale artificial iron fertilization of the Southern Ocean has been proposed as climate geo engineering strategy. The KEOPS results show that the verifiability of the CO₂ sink would require considerable efforts. The large data set collected during KEOPS should also stimulate new work in modeling the impact of iron fertilization, but also of other changes like stratification on the biological pump of CO₂.

Keywords: iron fertilization, carbon cycle, Southern Ocean

Oral presentation

Hg speciation in water column in South Atlantic Ocean along 40°S parallel

Bratkič A., Vahcic M., Obu Vazner K., Fajon V., Kotnik J. and Horvat M.

The oceans' water masses are globally important vectors and reservoirs of various Hg species. Hg natural cycle has been disrupted by anthropogenic activities and its acute toxicity makes it crucial to understand its transformations and fate with regard to the present and the future of the world's oceans. However, Hg ocean cycling is not yet completely understood, partly because many regions remain undersampled. During UK-GEOTRACES sampling campaign GA10 aboard RRS James Cook water has been collected along the 40° parallel in the South Atlantic Ocean to investigate Hg ocean's cycle. Onboard measurements of ocean water included determination of total Hg (THg) and dissolved gaseous mercury (DGM). Samples for monomethylmercury (MeHg) and dimethylmercury (DMeHg) were stored and measured in laboratory. Sampling was performed at very high vertical frequency of 20-24 depths per station, enabling an unprecedented insight into Hg speciation in this region.

THg was generally uniformly distributed throughout the water column with no apparent significant variation. The average was $0.32 \text{ ng/L} \pm 0.2 \text{ ng/L}$. Surface waters were depleted in comparison to deep and intermediate waters; and no apparent atmospheric Hg deposition was observed, despite concurrent Copahue volcano (Chile) activity with its plume reaching over South Atlantic. Westwards from Mid-Atlantic Ridge THg values increased slightly, reaching up to 0.46 ng/L , which was presumably the signal of geothermal activity of the ridge. Majority of MeHg concentrations were lower than 10 pg/L . However, an increase of MeHg (up to 30 pg/L) in surface waters from 0°W to 20°W was observed, co-occurring with increased Chlorophyll a abundance and a also decrease in transmittance. A correlation of MeHg and particulate suspended matter likely of biogenic origin is very likely. There was also a slight increase of MeHg concentrations between depths of 1500 m and 3000 m at 17°W and 42°W . These depths correspond to North Atlantic Deep Water (NADW) mass and may be contaminated from decades of intensive Hg anthropogenic use on northern hemisphere.

DGM results show a strong depletion in surface waters, indicating that this region of the ocean is a source of elemental Hg to the atmosphere. Concentrations ranged from 1.8 pg/L to 110 pg/L and represented between 0.9% and 56% of THg. NADW contained on average less DGM than Antarctic Intermediate Water (AAIW) and Antarctic Bottom Water (AABW), which may be due to its higher salinity. Upper Circumpolar Deep Water, which was rich in nutrients, showed also higher DGM concentrations. Overall, we have observed an interesting correlation between nitrate and DGM, both generally increasing with depth. There was a strong increase of DGM in Argentinean Basin from 3000 m to the bottom. The reason was unclear, since the ocean floor there is very old and has no known tectonic activities. DMeHg was determined at one station (50.9°W and 38.1°S) and increased significantly below 500 m. It was highest in AAIW with value of 8.3 pg/L ; however, it never represented more than 1.8% of THg.

Keywords: mercury, ocean cycling, biotransformations, speciation

Oral presentation

Future pH reductions put North Atlantic deep-sea ecosystems at risk

Gehlen M., Séférian R., Jones D.O., Roy T., Roth R., Barry J, Bopp L., Doney S.C., Dunne J.P., Heinze C., Joos F., Orr, J.C., Resplandy L., Segschneider J., Tjiputra J.

The global ocean is a net sink for anthropogenic carbon with an uptake since the onset of industrialization and up to 2010 estimated to $\sim 155 \pm 31$ Pg. The ongoing uptake of CO₂ causes important changes in seawater chemistry referred to as ocean acidification. While evidence from experimental and modelling studies converge to suggest that ocean acidification will put marine ecosystems at risk, little is known about the extent and amplitude of chemical changes across the deep-ocean. Deep-sea organisms might, however, be particularly vulnerable to changes in seawater chemistry owing to their evolutionary history, physical environment and present-day natural environmental variability. This study relies on seven fully-coupled Earth system models to quantify the amplitude of ocean acidification across the North Atlantic in response to four Representative Concentration Pathways (RCP). The North Atlantic (35°N-75°N, 90°W – 180°W) is a major region of deep-water formation resulting in the rapid propagation of surface-derived changes in carbonate chemistry to depth. The deep-sea harbours ecosystems of high bio-diversity on continental slope, seamounts and canyons (e.g. cold-water corals, sponge communities). Projected pH reductions by 2100 exceed -0.2 units for three out of the four RCPs and over more than 17% of the North Atlantic seafloor. A pH reduction of this amplitude exceeds both current natural variability and paleo-record-based estimates of changes in North Atlantic deep-water chemistry over the past ten-thousand years. Global warming results in an increase of stratification. This in turn is shown to slightly alleviate the impact of ocean acidification on the deep seafloor. In order to evaluate potential consequences of pH reductions on high biodiversity ecosystems we co-located chemical changes with seamounts and canyons. By the end of the 21st century and under the high CO₂ scenario RCP8.5, pH reductions exceeding -0.2 are projected for $\sim 23\%$ of North Atlantic deep-sea canyons and $\sim 8\%$ of seamounts, including seamounts proposed as sites of marine protected areas. Model projections suggest that impacts on biomes might be of the same magnitude or exceeding the current biodiversity target of 10% of preservation of marine biomes. Our results imply that ocean acidification may potentially offset benefits from conservation/management strategies relying on the regulation of resource exploitation.

Keywords: ocean acidification, North Atlantic, ecosystem impacts

Oral presentation

Quantifying the climate-driven processes leading to a reduced CO₂ uptake in the North Atlantic: A model study with the Bergen Climate Model

Goris N., Heinze C., Tjiputra J. and Schwinger J.

The key processes dominating the oceanic carbon uptake are carbon uptake at the surface and carbon transport from the surface into the oceans interior. Climate change effects both ocean circulation and temperature, changing the oceans capacity to absorb CO₂. In this context, the North Atlantic region is of special interest as it is one of the most important oceanic carbon sinks, featuring an exceptional high column inventory of anthropogenic CO₂. Since the latter is associated to deep water formation (Sabine, 2004), the CO₂-flux into the North Atlantic is expected to undergo significant changes with climate change. Quantifying the climate change induced CO₂-uptake variability and identifying its main drivers is of high relevance for the projection of future atmospheric CO₂ levels.

In order to quantify the above mentioned relationships, the present case study focuses on two simulations (denoted as 'COU' and 'BGC') with the Bergen Climate Model (BCM-C). Both simulations utilize carbon emissions based on observed records for the period 1850-1999, and the IPCC SRES-A2-emission scenario for 2000-2099. While simulation 'COU' is fully coupled, simulation 'BGC' implements a physical model that is not influenced by rising CO₂, leading to a carbon cycle simulation with rising atmospheric CO₂ but suppressed climatic change. Accordingly, the uptake differences between the two simulations illustrate the climate induced variability. Results of the case study confirm the important role of the North Atlantic for the carbon uptake, and demonstrate that this feature is most sensible to climate change (in comparison to other oceanic regions as defined in Tjiputra, 2010). In the absence of climatic changes, the integrated North Atlantic CO₂ uptake increases from 47.27 PgC (years 2000-2049) to 61.27 PgC (years 2050-2099). Changes in the climatic conditions reduce the uptake to 44.79 PgC and 53.80 PgC, respectively. The uptake reduction takes mainly place in the Subpolar Gyre accounting for 64.67% of the uptake differences. Further analysis shows, that the changing CO₂-flux in the Subpolar Gyre is caused by an increasing oceanic pCO₂, arising from a reduced Alkalinity-flux into the Subpolar Gyre region. Application of Singular Value Decomposition and Empirical Orthogonal Functions confirms that ocean circulation is one of the main drivers of the reduced CO₂ uptake within the North Atlantic.

Keywords: Reduced CO₂-uptake, North Atlantic, alkalinity, AMOC

Oral presentation

Anthropogenic CO₂ penetration in the Greenland Sea over the last decades

Jeansson E., Olsen A., Jutterström S., Lauvset S.

The Greenland Sea is one of the few places in the global oceans where deep mixing occurs, contributing to the surface-to-deep ocean transport of anthropogenic CO₂ (C_{ant}). Here we take a closer look at how the C_{ant} concentrations have evolved at this node of the ocean conveyor over the last three decades, in light of hydrographical and ventilation changes, and also discuss the implication for the surface to deep ocean anthropogenic carbon transport that takes place there. The analysis is based on the transit time distributions (TTD) approach applied on CFCs and hydrographical data from 1982 to 2009. The concentration of C_{ant} in the upper layer of the oceans is strongly linked to the atmospheric evolution of CO₂, but the penetration into the deep ocean, which represents the largest C_{ant} storage capacity in terms of its immense volume, relies on convective strength, and interior flow and mixing.

Presently (2009) C_{ant} concentrations in the upper 1500 m of the Greenland Sea is ~40 μmol kg⁻¹, and has clearly increased since 2002, when the typical concentration in this depth range was around 30-35 μmol kg⁻¹ (Olsen et al., 2006; Jutterström and Jeansson, 2008). In the deep waters, C_{ant} remained essentially steady at around 12 μmol kg⁻¹ between 2002 and 2009.

Our results reveal clear climate driven impacts on the penetration of anthropogenic carbon into the Greenland Sea, and during most of the 1990s and 2000s it appeared to be limited by the failure of convection to reach deeper than 1600 m in this area. This, in turn, may be linked to the predominant positive NAO phase in these two decades.

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Keywords: anthropogenic CO₂, Greenland Sea, ventilation, CFCs

Oral presentation

Variability of the ocean carbon cycle in response to El Niño-Southern Oscillation: impact of the climatological mean state

Keller K.M., Joos F. and Raible C.C.

The climate mode El Niño-Southern Oscillation (ENSO), located in the equatorial Pacific, is the most important factor concerning natural variability in the climate system on global scales. Additionally to winds, rainfall, circulation and thermocline depth (Fiedler, 2002), it is known to have substantial impact on variations of the ocean carbon cycle and biological productivity in the affected area (e.g., Le Quéré et al., 2010; Wanninkhof et al., 2013) and the global air-sea CO₂ flux in general (Siegenthaler, 1990; McKinley et al., 2004). We investigate the impact of ENSO on ocean biogeochemistry and export production by utilizing simulations with the earth system model NCAR CESM1. ENSO is represented by the NINO3.4 index, defined as the average sea surface temperature (SST) from 170°W–120°W and 5°S–5°N. The response of variables is investigated by applying composite analysis, thereby accounting for nonlinearity of positive and negative phases of ENSO. The impact of the climatological mean state is evaluated by comparing three different time periods: maunder minimum (1645-1715), the industrial period (1850-2005) and the 21st century (2005-2100, rcp8.5). The years 1850-2100 of the model simulations capture main characteristics of ENSO, including the occurrence at periodicities of 2 to 7 years and the highest variance during boreal winter (DJF). Yet, a comparison with the period 1645-1715 indicates a shift in frequency prior to the industrial period. Preliminary results for SST show the well-known warm- and cold tongues associated with El Niño and La Nina, sections of temperature through the equatorial Pacific illustrate the according east-west seesaw pattern in the thermocline. The composites for biogeochemical variables show related patterns. However, the results imply a weakening of the response of the ocean carbon cycle towards ENSO-forcing over time. For export production, this tendency is not present. However, here the results suggest a propagation of export production anomalies towards the east over time.

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Keywords: Ocean Carbon Cycle, Climate Change
Oral presentation

Time of Emergence of trends in ocean biogeochemistry

Keller K.M., Joos F. and Raible C.C.

For the detection of climate change, not only the magnitude of a trend signal is of significance. An essential issue is the time period required by the trend to be detectable in the first place. An illustrative measure for this is Time of Emergence (ToE), i.e., the point in time when a signal finally emerges from the background noise of natural variability. We investigate the ToE of trend signals in different biogeochemical and physical surface variables utilizing a multi-model ensemble comprising simulations of 17 ESMs. We find that signals in ocean biogeochemical variables emerge on much shorter timescales than the physical variable sea surface temperature (SST). The ToE patterns of pCO₂ and pH are spatially very similar to DIC, yet the trends emerge much faster - after roughly 12 years for the majority of the global ocean area, compared to between 10-30 years for DIC and 45-90 years for SST. In general, the background noise is of higher importance in determining ToE than the strength of the trend signal. In areas with high natural variability, even strong trends both in the physical climate and carbon cycle system are masked by variability over decadal timescales. In contrast to the trend, natural variability is affected by the seasonal cycle. This has important implications for observations, since it implies that intra-annual variability could question the representativeness of irregularly seasonal sampled measurements for the entire year and, thus, the interpretation of observed trends.

Keywords: Ocean Carbon Cycle, Climate Change

Poster presentation

Effects of CO₂ on phytoplankton-mediated micro- and macronutrient cycling

King A.L.

Phytoplankton are inextricably linked to ocean biogeochemistry through the uptake and transformation of major and trace elements. Due to their reliance on inorganic C for photosynthesis, rising CO₂ in the world's oceans will likely result in changes to nutrient requirements, elemental stoichiometry, and ultimately the flow of C and N through higher trophic levels and export to the deep sea. Experiments with unialgal cultures and natural community mesocosms suggest that the response of phytoplankton to CO₂/pH manipulations varies between taxa, and in some cases within genera. In some cases, elevated CO₂ significantly increased C:P and N:P molar ratios and reduced trace metal:P molar ratios. Experiments addressing the influence of CO₂ and other long-term changes on phytoplankton-mediated processes is necessary for our understanding of biogeochemistry of nutrient elements in future oceans.

Keywords: phytoplankton nitrate trace metals ocean acidification

Poster presentation

Response of diatom *Chaetoceros socialis* to a changing climate and dust deposition: role of iron

Li X., Røevros N. and Chou L.

Iron (Fe) plays an essential role in controlling the marine primary productivity and the efficiency of biological carbon pump through many important biogeochemical processes. It is considered as an important trace element which has a strong link to climate change and the sequestration of atmospheric carbon dioxide (CO₂). Also, Fe has been shown to be a limiting micronutrient for phytoplankton growth over vast areas of the modern ocean, in particular, the HNLC (High Nutrient Low Chlorophyll) regions where the dissolved iron concentrations in surface waters are extremely low. Besides upwelling and diffusion, aeolian dusts constitute the major external Fe input to the open ocean. There is thus an urgent demand to reduce the uncertainties in the assessment of the solubility and bioavailability of Fe upon mineral dust deposition and to improve our understanding of its impact on phytoplankton growth especially under changing climate. For instance, the two major consequences induced by the increasing CO₂ emissions: (i) global warming, which increases the seawater temperature and thereby intensifies upper ocean stratification, and (ii) ocean acidification, which decreases the pH of seawater, could modify the marine Fe (bio)geochemistry and bioavailability.

In this study, we have conducted laboratory culture experiments using a coastal marine diatom, *Chaetoceros socialis*, under controlled conditions (temperature, light intensity, pCO₂, dissolved Fe concentration, etc.) to evaluate how global climate change processes, in particular, changing dust deposition, sea-surface warming and ocean acidification, would affect iron speciation and bioavailability and the interrelationship among these changes. Diatoms are cultured in sterilized f/20 media, prepared with filtered (0.2 µm) North Atlantic aged seawater, at two temperatures (13°C and 18°C) and two pCO₂ corresponding to present-day (400 µatm) and near-future (800 µatm) conditions. Various parameters are followed regularly: pH, alkalinity, optical property (fluorescence), nutrients (dissolved nitrate, phosphate and silicate), dissolved Fe, cell abundance, chlorophyll-a, biogenic silica (BSi), particulate organic carbon and nitrogen (POC/PN). Fe(II) and Fe(III) speciation is determined using the ferrozine method. Mineral dusts (<63 µm) used in the experiments were sampled from the Kubuqi Desert, Inner Mongolia Autonomous Region, China.

The present study demonstrates clearly the influence of ocean acidification on the release of Fe upon dust deposition. They also show that atmospheric dust particles could provide a readily utilizable source of Fe and other macronutrients (dissolved silicate and phosphate) for phytoplankton growth and promote thus primary production. The results obtained are discussed in relation to global warming and ocean acidification. Future experiments are proposed, aiming at obtaining a more complete picture of how global change would affect marine phytoplankton, in relation to Fe biogeochemistry, especially in a future high CO₂ ocean.

Keywords: Diatoms, global warming, ocean acidification, iron biogeochemistry, dust deposition

Poster presentation

The role of the Southern Ocean in global carbon cycling

Morée A.L.

As a major deep water formation and -ventilation region, the Southern Ocean is considered to play an important role in global carbon cycling. The goal of this (PhD) study in progress is to quantify the role of the Southern Ocean in regulating the atmospheric CO₂ concentration.

The research aims are I) to extend our knowledge of Southern Ocean key biogeochemical and physical processes by comparison of model studies (MICOM-HAMOCC, NorESM) with observational data, II) to gain improved insight in anthropogenic CO₂ sequestration in the Southern Ocean for both the present and future and III) to explore the role of the Southern Ocean in the glacial-interglacial CO₂ draw down.

At present, a good model representation of the Southern Ocean is limited by data scarcity and process complexities. Newly available data and knowledge will be used to improve the current model version. First, pre-industrial Southern Ocean biogeochemistry representations are improved using a multi-tracer approach, thereby comparing observations with model results. This provides insight in model deficiencies and key processes of the Southern Ocean. Then, the implementation of ¹³C and ¹⁴C isotopes into the MICOM-HAMOCC model will help to explore the model functioning on biological production, ocean circulation and gas exchange (¹³C), large scale marine circulation and water mass analysis (¹⁴C). Since ¹³C provides insight in the non-natural carbon present in the system, addition of this tracer in the model can improve model representations of anthropogenic influences on the carbon cycle. A key focus will be on surface production and its downward fluxes (organic matter formation and fate).

Based on the revised model, multiple model experiments will be done. These will be focused on I) the model outcome compared to observations, II) the role of surface production changes in the Southern Ocean for the global carbon cycle and III) glacial-interglacial forcing mechanisms in the Southern Ocean.

Preliminary results of the multi-tracer comparison will be presented and the modeling strategy will be discussed.

Keywords: Southern Ocean, carbon cycling, modelling, MICOM-HAMOCC/NorESM

Poster presentation

Unexpected increase in the simulated marine oxygen inventory in a warmer future ocean

Oschlies A.

An Earth system model of intermediate complexity (UVic) is employed to simulate the impact of global warming on marine oxygen and nutrient budgets to anthropogenic CO₂ emissions on millennial timescales. A surprising finding is that the simulated marine oxygen inventory of the warmer future ocean exceeds the preindustrial oxygen inventory. An initial deoxygenation continues for a few hundred years and leads to a substantial expansion of oxygen minimum zones. This trend is eventually reversed via oxygen feedbacks on the nitrogen cycle, generating a net loss of nitrate via denitrification, which in turn results in a net oceanic oxygen gain. Sensitivities of the simulated increase in the marine oxygen inventory to assumptions about various redox-sensitive processes are discussed, as are implications for our understanding of the generation of past oceanic anoxic events.

Keywords: deoxygenation, nitrogen cycle, global warming

Oral presentation

Insight into the fate of newly-fixed nitrogen in a high CO₂ ocean

Paul A.J., Boxhammer T., Lischka S., Stuhr A., Bach L. and Riebesell U.

The supply of bioavailable nitrogen to the surface ocean controls productivity in large areas of the global ocean. Changes in bioavailable nitrogen inputs and loss processes due to ocean acidification are likely, however the consequences on the pelagic nitrogen cycle are not yet clear. This project investigated nitrogen flow into key pools in the pelagic nitrogen cycle driven by diazotrophic organisms in a future high-CO₂ ocean scenario.

Five large-volume mesocosms of different pCO₂ deployed in the Finnish archipelago were enriched with ¹⁵N as a tracer enabling the diazotrophically-fixed nitrogen to be tracked through the food web. Nitrogen-fixing cyanobacteria provide an important nitrogen input in this region annually. Results will be presented on the flow of diazotrophic nitrogen through the enclosed natural plankton community into different nitrogen pools and the potential for changes due to increased pCO₂ will be highlighted. Initial analyses indicate changes in the pelagic nitrogen cycle were only small between pCO₂ treatments and differences were most likely driven by changes in the plankton community.

Keywords: ocean acidification, nitrogen, diazotrophs

Oral presentation

Exchange dynamics and storage of nitrogen in a tropical mangrove ecosystem

Ray R., Das S., Majumder N., Chowdhury C., Janab T.K.

Biogeochemical pathway of nitrogen in the mangrove ecosystem is very complex and dynamic due its transformation into different oxidation state under different environmental settings. This study applied a simple and straightforward box model approach to assess the nitrogen budget in the Indian Sundarbans, world's largest delta and heritage site. Results showed that Sundarbans acts as a sink for atmospheric nitrogen in terms of NO_x, NH₃, N₂, and water column dissolved inorganic nitrogen. The coupling of biosphere and atmosphere in terms of atmospheric NO_x and NH₃ uptake showed that uptake of ammonia (0.359 nmol cm⁻²hr⁻¹) was about 18 fold as large as that of NO_x (0.02 nmol cm⁻²hr⁻¹). The nitrogen stored by processes such as plant uptake from the atmosphere, nitrogen fixation, and sediment water exchange was 1.4 times as large as that of recycled nitrogen from litter and could account 67.6% of nitrogen required for mangrove net production. Most of the nitrogen was conserved in the living biomass (living biomass: 1653 kg N ha⁻¹ versus soil: 375 kg N ha⁻¹). The loss of nitrogen was 19.8% of the total amount that was conserved from the external sources in the Sundarban mangrove system. Conclusively Sundarban mangroves could retain 0.13% (88t) of the annual river flux of nitrogen to the coastal water and fix considerable nitrogen (11.95±4.49 nmol cm⁻²hr⁻¹) from the atmosphere allowing less emission and promoting higher conservation within the system

Keywords: Nitrogen, mangrove, living biomass, sediment, Sundarbans

Poster presentation

Different response of the natural and the anthropogenically disturbed ocean carbon cycle to changing climate

Schwinger J., Tjiputra J. and Heinze C.

It is often assumed that the carbon cycle reacts to rising CO₂ levels and to warming climate independently. That is, the total carbon cycle feedback can be expressed as the sum of a carbon-concentration feedback (reaction to rising CO₂) and a carbon-climate feedback (reaction to rising temperature). For the Coupled Model Intercomparison Project Phase 5 (CMIP5), radiatively (RAD) and biogeochemically (BGC) coupled simulations have been undertaken to better understand carbon cycle feedback processes. In the RAD simulations only the radiation code of the models "see" rising CO₂, while the biogeochemical modules see preindustrial CO₂ levels. Hence, carbon fluxes in these model runs reflect the response of the natural carbon cycle to changing climate. The biogeochemically coupled experiments, where only the biogeochemistry modules see the rising CO₂ levels, allow us to estimate the carbon-concentration feedback. Importantly, the carbon uptake difference between the fully coupled (standard) simulation and BGC reflects the reaction of the anthropogenically perturbed carbon cycle to climate change.

Our results indicate that the weakening of carbon uptake is less (by 19 to 58 Pg carbon) for the natural compared to the anthropogenically disturbed ocean carbon cycle. This non-linearity is small compared to the total ocean carbon uptake (533 to 676 Pg C), but it is of the same order as the carbon-climate feedback. The weakening of ocean circulation and mixing with climate change makes the largest contribution to the non-linear carbon cycle response, since carbon transport to depth is suppressed in the fully relative to the biogeochemically coupled simulations, while the radiatively coupled experiment mainly measures the loss of near surface carbon due to warming the ocean. Sea ice retreat and seawater carbon chemistry contribute less to the simulated non-linearity. Our results indicate that estimates of the ocean carbon-climate feedback derived from a "warming only" (radiatively coupled) simulation may underestimate the reduction of ocean carbon uptake in a warm climate high CO₂ world.

Keywords: carbon cycle feedback, CMIP5

Poster presentation

Estimating the influence of “non-Redfield” dissolved organic matter cycling on the global oceanic fixed nitrogen inventory in the modern and glacial oceans

Somes C. and Oschlies A.

Nitrogen is one of the major limiting nutrients in the ocean that prevents biological production and carbon export into the ocean interior, known as the biological carbon pump. The major source and sink processes for the oceanic fixed nitrogen budget, N fixation and denitrification, respectively, are sensitive to climate change. We force an Earth System Climate Model of intermediate complexity that includes three-dimensional modules ocean biogeochemistry and isotopes (MOBI) with boundary conditions from the Last Glacial Maximum (LGM: ~21,000 years ago) and show that the nitrogen isotope results are qualitatively consistent with a global sedimentary database. Water column denitrification, which occurs in oxygen minimum zones, decreases by a factor of ~2 due to increased oxygen solubility in the glacial surface ocean that is ~2°C cooler on the global average. Sedimentary denitrification also decreases by a factor of ~2 due more exposed continental shelves from reduced sea level. We conduct experiments showing how N fixation responds in a “Redfield” biogeochemical model with constant elemental stoichiometry (N:P=16) and another “non-Redfield” experiment that includes a higher N:P quota for nitrogen fixers (N:P=40) and preferential remineralization of dissolved organic phosphorus relative to nitrogen (3 times faster). This “non-Redfield” experiment produces a more realistic distribution of dissolved organic nitrogen and phosphorus in the modern ocean and stimulates additional N fixation due to less P limitation of N fixers. It predicts that the glacial oceanic fixed nitrogen inventory was >10% larger than present, whereas the “Redfield” model predicts an increase of <5%. Our experiments show the importance of including non-Redfield stoichiometry in marine biogeochemical models when estimating changes to N fixation.

Keywords: nitrogen fixation dissolved organic phosphorus glacial

Oral presentation

Cell viability and chlorophyll alteration in Eukaryote phytoplankton; A seasonal cycle in the western English Channel

Steele D.J., Airs R.L., Kimmance S.A., Franklin D.J.

Large proportions of dead phytoplankton cells can accumulate in the water column^(1,2), thereby contributing to ocean colour, but not to primary production. The rates and processes of phytoplankton death are likely to be major contributors to the variability of oceanic primary productivity. A developing approach for determining phytoplankton viability exists in the detection of early alteration products of chlorophylls. These have been detected during the senescence of several species^(3,4), with product type changing with cause of cell death (nutrient/light limitation or viral lysis). Chlorophyll alteration products were detected by HPLC and LCMS in the Western English Channel, UK during 2012. Alteration products were analysed together with phytoplankton community composition and population density, nutrient conditions and telemetry data such as temperature and PAR. High rainfall and riverine nutrient input during spring 2012, combined with low average PAR and a mixed water column caused a prolonged spring bloom with low cell density, compared with previous years. At the onset of decline of the diatom spring bloom the chlorophyll-a allomer hydroxy-chlorophyll-a reached a maxima (relative to chl-a). Hydroxy-chlorophyll-a was also an indicator of viral lysis (but not nutrient limitation), in a batch culture study of *Ostreococcus tauri*. Membrane permeability and cellular reactive oxygen species were also monitored; analyses which are difficult to apply to mixed, natural samples. The prospects for detecting cell viability from pigment alteration products and its implications for our understanding of ocean primary production will be discussed.

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(2) Hayakawa, M., Suzuki, K., Saito, H., Takahashi, K., and Ito, S. (2008). *Journal of Experimental Marine Biology and Ecology* 360, 63-70.

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Keywords: Primary production, Time-series, Viability, Virus

Poster presentation

Stimulation or limitation of phytoplankton biomineralization under rising CO₂?

Stoll H.M., Bolton C., Mejia Ramirez L.M., Isensee K., Mendez Vicente A.

The biomineralization of coccolithophores and diatoms plays a key role in the ocean carbon cycle through their contribution to aggregation and ballasting of organic carbon. The predicted changes in ocean stratification, pH, and dissolved CO₂ are likely to alter the extent of mineralization by these algae and potentially their relative dominance in different ecosystems.

Coccolithophores are unique in that they use carbon for both photosynthesis and calcification. We develop a new inverse model of carbon allocation in the cell, the Acti-Co model. In inverse simulations, this model is driven by the isotopic composition of carbon in the calcite and organic matter. This data show that when carbon dioxide levels are low, coccolithophorids in culture reallocate HCO₃⁻ from photosynthesis to calcification. This provides the first evidence that competition between photosynthesis and calcification is widespread and occurs in several different species, and that at limiting CO₂, HCO₃⁻ allocation to biomineralization is sacrificed. Our examination of coccoliths in the fossil record shows that this shift in allocation from calcification to photosynthesis occurred relatively recently (7-5 million years ago) and at a relatively low pCO₂ threshold of 375-575 ppm (Bolton and Stoll, Nature, 2013) and therefore may be reversed within decades. This raises the possibility that calcification by coccolithophorids may be enhanced, rather than jeopardized, by rising CO₂ aq. We further explore the potential consequences on the PIC/POC ratio of changes in light regime which may arise from greater stratification in the subtropical gyres, and the experimental and evolutionary interplay between PIC/POC and cell size as a function of CO₂.

In contrast to coccolithophorids, diatom biomineralization does not require C and shows a different response to C limitation. In our culture experiments in three species of diatoms, the degree of biomineralization of the cells (Si/C ratio) decreased with increasing CO₂ aq concentration in the media. This response is coherent with previous suggestions that the biomineral may serve a buffer to maintain optimal near-cellular pH for enzymes required for boosting cellular C acquisition, which are most significant at low CO₂ availability. The B content of diatoms appears to track the significance of these carbon concentrating mechanisms, potentially because borate is co-transported by bicarbonate transporters into the cell, and may be an indicator of diatom response to CO₂ in sediment and field populations.

Over the last 50 million years as CO₂ has declined, coccolithophores have diminished in importance relative to diatoms in the global ocean. We suggest that the increasing reallocation of HCO₃⁻ from calcification to photosynthesis may have contributed to the competitive disadvantage of coccolithophores.

Keywords: calcification, ocean acidification, coccolithophorids, diatoms

Oral presentation

Scavenging dynamics of jellyfish versus fish falls at the deep seafloor

Sweetman A.K., Smith C.R. and Jones D.

In recent years, numerous studies have documented large accumulations of dead jellyfish at the deep seafloor. These observations suggest that gelatinous zooplankton carcasses (jellyfish falls) may provide an important transport vector for carbon and nitrogen to the seabed, because jellyfish are renowned for their ability to rapidly form massive, yet often short-lived blooms. Mass mortality of blooming jellyfish could therefore become very important for deep-sea energetics on local scales that match the scale of jellyfish blooms in overlying waters. To assess the importance of jellyfish falls to deep-sea food-webs, we used insitu time-lapse photography to compare the diversity of deep-sea scavengers, as well as scavenging rates on jellyfish and fish baits at 1300m depth. We found remarkably similar scavenging communities consumed the jellyfish and fish baits. The scavenging response to jellyfish baits was also extremely rapid, with most of the bait being consumed within hours. No significant difference was detected between scavenger assemblages, scavenging rates on fish and jellyfish baits or rates of C, N and energy transfer to scavengers at fish and jellyfish baits. Scavenging rates on jellyfish and fish baits were not correlated to calorific content. Rapid removal of jellyfish by scavengers suggests that jellyfish are an important food group for many scavengers, and are not necessarily a trophic dead end in the deep sea. Ultimately, our data suggests that the flux of gelatinous material to the deep seafloor may be much higher than previously estimated, and the role of gelatinous zooplankton in pelagic-benthic coupling may be seriously underestimated.

Keywords: Jellyfish, Organic falls, Scavenging, Deep sea

Oral presentation

Session C1: Beyond 'Z': what modellers need and empiricists have to offer to better incorporate higher trophic levels and humans in end-to-end models

Oral Presentations

Friday 27 June, 10:30-12:00 Parallel session 8

Room K1

Time	Name	Title
10:30-10:45	Weng, Kevin	Fish responses to changes in oxygen and interactions of climate stressors
10:45-11:00	Watermeyer, Kate	Frame-based modelling of changes in small pelagic fish abundance and distribution in the southern Benguela
11:00-11:15	Reglero, Patricia	Worldwide distributions of tuna larvae: environmental requirements for tuna spawning habitats
11:15-11:30	Radtke, Hagen	Constructing end-to-end models in a Eulerian framework
11:30-11:45	Costa, Daniel	Top Predators Impact Marine Communities in Multiple Ways
11:45-12:00	All	General Discussion

Top Predators Impact Marine Communities in Multiple Ways

Costa D., Roman J., Estes J., Morissette L., Smith C., McCarthy J., Nation J.B., NicolS., Pershing A. and Smetacek V.

Marine mammals are large and include the largest animals to have ever lived on the planet. With high metabolic rates and plentiful populations, marine mammals exerted significant influences on marine ecosystems before industrial exploitation of whales and seals: as consumers of fishes and invertebrates; as prey to other large-bodied predators; as reservoirs and vertical and horizontal vectors for nutrients; and as detrital sources of energy and habitat in the deep sea. Their depletion has likely altered the structure and function of the oceans and as a result their role in structuring marine ecosystems has not been fully appreciated. This presentation will examine the above attributes of marine mammals as ecosystems engineers.

Keywords: marine mammals, top predators, trophic ecology

Oral presentation

Constructing end-to-end models in a Eulerian framework

Radtke H.

In spatially resolved end-to-end models, the representation of piscivorous fish remains a major challenge. Only few studies exist where a two-way predator-prey-interaction between fish species has been implemented. Part of the difficulty is technical and arises from the representation of fish by superindividuals which has become a commonly used method. As an alternative, we present a Eulerian approach where NPZD variables, prey fish and predators share the same horizontal grid. For the example of the Baltic Sea, we show how pre-existing models originating from fisheries science can be linked together to form a fully coupled and spatially explicit end-to-end model system. A mass-conserving, size-based formulation of predator-prey interaction by Fennel et al. (2008) serves as a link between the sub-models for herring, sprat and cod. Horizontal migration of fish is taken into account by a special movement algorithm and driven by foraging and the movement to prescribed spawning areas.

Keywords: end-to-end eulerian model baltic sea predator-prey-interaction

Oral presentation

Worldwide distributions of tuna larvae: environmental requirements for tuna spawning habitats

Reglero P., and Tittensor D

There is very limited scientific information on the spatio-temporal spawning patterns of tuna species and strong uncertainties in the knowledge of many biological parameters, including reproduction. In general, it is very difficult to obtain empirical data to test worldwide spawning distributions. Herein we have compiled and analyzed data on the global distributions of larval occurrence for all major oceanic tuna species to investigate environmental predictors of larval habitat. Our results showed that temperature requirements explained much of the variation in larval occurrence and demonstrate that tuna larvae have elevated probability of occurrence at intermediate values of eddy kinetic energy, i.e. areas with mesoscale oceanographic activity. However, some deviations to this pattern are also observed. We provide a globally comprehensive dataset of tuna larval occurrence compiled from geo-referenced records of larval presence and absence across all oceans, and analyze its limitations. Its availability for the research community could assist with further collaborative research that will help to disentangle global drivers in tuna distributions. The mechanisms linking larval development and survival in relation to the two variables (SST and EKE) remain speculative, but likely relate to speed of development, larval retention, and locally enhanced productivity. The identified oceanographic parameters should be considered when including larval habitats and spawning distributions in more complex models.

Keywords: tuna, worldwide, spawning, environment

Oral presentation

Frame-based modelling of changes in small pelagic fish abundance and distribution in the southern Benguela

Watermeyer K., Jarre A. and Shannon L.J.

A number of ecologically and economically important species in the southern Benguela (sardine *Sardinops sagax*, anchovy *Engraulis encrasicolus*, rock lobster *Jasus lalandii*) have undergone southward/ eastward shifts in their distribution in recent decades. In addition to the resultant changes in the availability of these species as prey for top predators such as seabirds, the spatially-distinct nature of the system - the west coast characterised by seasonal, wind-driven upwelling, and the south coast with characteristics of both a shelf system and an upwelling system – means the location of a stock within the system has implications for its productivity. The spatial dynamics of small pelagic fish are of particular importance because they are thought to exert wasp-waisted trophic control on the system. An objective-driven model is constructed to investigate the ability of a frame-based modelling approach to describe spatial dynamics of sardine and anchovy, and to explore the implications of possible management options within this model. Frames are identified representing possible stable states of abundance and spatial distribution, and the characteristics of the underlying population models in each of these potential states determined. The spatial and population dynamics of sardine and anchovy are then modelled, assuming climate variability and pressure from the small pelagic fishery as drivers determining when the model switches between frames. The frame-based modelling approach does appear to be useful within this context, allowing the implications of various assumptions regarding environment and fishing pressure as drivers to be explored, as well as the possible implications at a system level in terms of availability of prey to top predators. Results suggest that the productivity of the sardine resource within the model is highly dependent on the spatial characteristics of the fishing pressure it experiences, however the role of anchovy within with model system has not yet been fully developed, and further effort in this area may allow for more robust results. Increasing our understanding of the relative suitability of environmental conditions of different regions is also important if we are to increase our capacity to predict trends in abundance and distribution.

Keywords: Ecosystem approach; frame-based modelling; sardine; anchovy

Oral presentation

Fish responses to changes in oxygen and interactions of climate stressors

Weng K.C., Raye G.D., Comfort C.M., Perez Andujar G. and Garcia D.

In the future, marine fishes are likely to get squeezed by warming, stratification, deoxygenation at depth, and acidification. Some species may be pre-adapted to habitats that will likely expand in the future, while others may experience a contraction of suitable habitat. We compare the behavior of high trophic level species that have contrasting adaptations to hypoxia, and look at adaptations to their respective habitats. The tunas are 'energy speculators' that require high oxygen environments, and have a range of adaptations to high metabolic rate. In contrast, species inhabiting the oxygen minimum layer, such as the bluntnose sixgill shark, have adaptations to energy conservation and low metabolic rate. Future ocean conditions may favor energy conserving adaptations across large regions. Since hypoxia interacts with temperature and pH in its physiological impact, we develop a model to predict performance under a range of present and future scenarios. This model could potentially be used to incorporate the effects of pH into existing ecosystem models that are driven by temperature, oxygen and productivity.

Keywords: oxygen, hypoxia, acidification, warming, shark

Oral presentation

Session C3: Integrated studies of the impact of climate change on marine ecosystems

Oral presentations

Tuesday 24 June, 16:00-17:30 Parallel session 3

Topic: Combined approaches (experimentation, modelling, and observations)

Chairs: Sakina-Dorothee Ayata & Rubao Ji

Room K3

Time	Presenter	Title
16:00-16:10	Ayata, Sakina-Dorothee	Introduction
16:10-16:30	Calbet, Albert	Future climate scenarios for a productive coastal planktonic food web resulted in changed microbial grazer dynamics and phenology, and decreased trophic transfer efficiency
16:30-16:50	Ravagnan, Elisa	Modelling the combined effects of ocean acidification, climate change and oil related discharges on the northern shrimp <i>Pandalus borealis</i>
16:50-17:10	Yoon, Joo-Eun	Primary productivity and its interannual variability in the East Sea, 1998-2007
17:10-17:30	All	Discussion

Wednesday 25 June, 11:00-12:30 Parallel session 4

Topic: Impact on biogeography and species distribution

Chairs: Rubao Ji & Øystein Varpe

Room K3

Time	Presenter	Title
11:00-11:20	Cheung, William	Assessing the integrated impacts of climate change and fishing on biogeography of marine species
11:20-11:40	Boyce, Daniel	Macro-ecological patterns and drivers of trophic control across marine ecosystems
11:40-12:00	Alabia, Irene	Potential impacts of warming ocean to neon flying squid habitat in western and central North Pacific
12:00-12:20	Shannon, Lynne	Synthesis: Climate effects on biodiversity, abundance and distribution of marine organisms in the Benguela
12:20-12:30	All	Discussion

Session C3: Impact of climate change

Wednesday 25 June, 14:00-15:30 Parallel session 5

Topic: Impact on dispersal, recruitment, and populations

Chairs: Trond Kristiansen & Øystein Varpe

Room K3

Time	Presenter	Title
14:00-14:20	Daewel, Ute	About the predictive potential of early life stage IBMs: an example for Atlantic cod (<i>Gadus morhua</i>) in the North Sea
14:20-14:40	Myksvoll, Mari	Impacts of climate variability on recruitment in an arctic seabird population
14:40-15:00	Botsford, Louis	Scaling Up from Effects at the Individual Level to Population and Ecosystem Levels via Stochastic Population Models
15:00-15:20	Asch, Rebecca	Will Climate Change Result in Increased Mismatches between Phytoplankton Blooms and Fish Phenology?
15:20-15:30	All	Discussion

Wednesday 25 June, 16:00-17:30 Parallel session 6

Topic: Impact on marine communities

Chairs: Gabriel Reygondeau & Trond Kristiansen

Room K3

Time	Presenter	Title
16:00-16:20	Hjøllø, Solfrid	Impact of climate change on lower tropic levels in the Barents Sea
16:20-16:40	Lefort, Stelly	Climate change impacts on global pelagic communities
16:40-17:00	Eddy, Tyler	Predicting climate change impacts on marine ecosystems using GCMs, laboratory experiments, and ecosystem modelling
17:00-17:30	All	Discussion

Thursday 26 June, 14:00-15:30 Parallel session 7

Topic: Impact on food webs

Chairs: Sakina-Dorothee Ayata & Gabriel Reygondeau

Room K3

Time	Presenter	Title
14:00-14:20	Planque, Benjamin	How can increased temperature affect the dynamics of the Barents Sea food web?
14:20-14:40	Milisenda, Giacomo	Trophic ecology and bioenergetics of a planktonic predator: jellyfish <i>Pelagia noctiluca</i> .
14:40-15:00	Salvanes, Anne Gro Vea	Spatial dynamics of the bearded goby and its key fish predators off Namibia varies with climate and oxygen availability
15:00-15:30	All	Discussion

Session C3: Impact of climate change

Poster presentations

Tuesday 24 June, 17:30 Poster Session 1

ID	Presenter	Title
C3.P1	Ayata, Sakina-Dorothee	Projected distributions of planktonic organisms under different climate change scenarios for the Mediterranean Sea
C3.P 2	Gessner, Mark	A Large Experimental Platform to Study Climate-Change Effects on Freshwater Ecosystems - The LakeLab
C3.P 3	Koenigstein, Stefan	A social-ecological model of climate change impacts on marine ecosystems: Integrating experimental results and ecosystem service uses
C3.P 4	Kristiansen, Trond	Turbulence enhances feeding of larval cod at low prey densities
C3.P 5	Lobanova, Polina	Variability of primary production in the Okhotsk Sea and its correspondence to the hydro-dynamic processes
C3.P 6	Rahman, S.M. Mustafizur	Regional responses of marine environment and fisheries resources in the East/Japan Sea related to climate-ocean forcing
C3.P 7	Salvanes, Anne Gro Ve	Reproduction and growth of the suboxic tolerant bearded goby on the Namibian shelf of Benguela
C3.P 8	Sempéré, Richard	MERMEX project, objectives and first results

Potential impacts of warming ocean to neon flying squid habitat in western and central North Pacific

Alabia I., Saitoh S.-I., Igarashi H., Ishikawa Y. Usui N., Kamachi M., Awaji T. and Seito M.

We investigated the plausible impacts of ocean warming associated with projected climate changes on inferred potential habitat of neon flying squid in western and central North Pacific. From a suite of monthly-compiled environmental variables and squid fishery data from May-July 2000-2010, we used maximum entropy (MaxEnt) algorithm to generate a parsimonious model to elucidate squid potential habitat in the area. The environmental parameters in final base model used for future climate habitat mapping were sea surface temperature (SST), sea surface salinity, sea surface height and net primary productivity. These were selected due to their significant model contribution relative to the rest of environmental data (eddy kinetic energy, mixed layer depth, wind stress curl, chlorophyll-a, zonal and meridional geostrophic velocity components). Future squid habitat predictions for May-July 2025, 2050 and 2100 were made using SST projections from MIROC3.2h (Model for Interdisciplinary Research on Climate), CSIRO-MK3.5 (Commonwealth Scientific and Industrial Research Organisation) and GDFL-CM2.1 (Geophysical Fluid Dynamics Laboratory) IPCC-SREA1B climate models. Habitat suitability index (HSI) maps from MIROC3.2h and CSIRO-MK3.5 SST projections showed higher HSI magnitude with wider spatial extent relative to that of HSI maps derived using GDFL-CM2.1. Habitat changes characterized by northward habitat shift coupled with a pronounced reduction (CSIRO-MK3.5) and eventual disappearance of inferred squid habitat (MIROC3.2h and GDFL-CM2.1) were also observed from May-July 2025-2100. These results could lend vital insights for fishery resource management under changing climate.

Keywords: Ocean warming; squid habitat; North Pacific

Oral presentation

Will Climate Change Result in Increased Mismatches between Phytoplankton Blooms and Fish Phenology?

Asch R.G., Stock C.A. and Sarmiento J.L.

Fish and phytoplankton phenology will both likely be affected by climate change. However, since distinct oceanic processes influence the timing of phytoplankton blooms and the reproductive physiology of fishes, their rates of phenological change may differ. This could lead to an increased frequency of seasonal mismatches between the abundance of larval fishes and their planktonic prey, with negative consequences for fisheries. We used the GFDL Earth System Model (GFDL ESM2M) to examine projected changes in fish and phytoplankton phenology throughout the 21st century based on the RCP 8.5 climate change scenario. Globally, the mean dates of phytoplankton bloom initiation and termination simulated by ESM2M were correlated with SeaWiFS at $r \geq 0.61$. ESM2M exhibited less skill identifying the mean duration of phytoplankton blooms ($r = 0.33$). At latitudes $>40^\circ$ N, bloom initiation is projected to become earlier, changing at a mean rate of 1.4 days decade⁻¹. Bloom termination dates also displayed phenological advancement across this region. In the Arctic, changes in bloom termination occurred more rapidly than shifts in bloom initiation. This caused Arctic bloom duration to shorten by ~ 1 month over the 1950-2099 period. Widespread changes in phytoplankton phenology were not observed in subtropical and equatorial regions. Since ESM2M does not explicitly include higher trophic level organisms, we made the following assumptions to model the spawning phenology of temperate, epipelagic fishes: (1) During a baseline period prior to detectable effects of anthropogenic climate change (1901-1950), we assumed that on average fishes spawned at the same time as the start of the spring bloom; (2) Interannual variations in spawning phenology reflect changes in cumulative degree days between the time of the annual SST minimum and the spring bloom, and; (3) We initially concentrated on fishes with spawning grounds associated with stable geographic features whose locations are unlikely to vary under climate change. Projected changes in fish phenology were modeled during the years 2050-2099 assuming that spawning would continue to occur at a constant number of degree days in absence of any genetic or behavioral adaptation by fishes. Across nearly all areas $>40^\circ$ N, fishes shifted their phenology to spawn earlier at a faster rate than the shift in the spring phytoplankton bloom. Consequently, across 63% of our study area, phenological mismatches between fishes and phytoplankton blooms exceeded one month. The asynchrony between these events is large enough to exceed the duration of the egg and yolk-sac larvae stages of many fishes, indicating that low plankton abundance would affect exogenous feeding and result in higher larval mortality and the potential for decreased fisheries recruitment. Future work will examine whether phenological mismatches may be ameliorated by range shifts where changes in spawning habitat track changes in isotherm locations.

Keywords: Match/mismatch hypothesis, phenology, fish spawning, phytoplankton

Oral presentation

Projected distributions of planktonic organisms under different climate change scenarios for the Mediterranean Sea

Benedetti F., Guilhaumon F., Reygondeau G., Somot S., Ayata S.-D.

Especially through warming of sea waters, global climate change is expected to induce major transformations in marine ecosystems, such as phenological shifts, trophic mismatch, or polewards migrations. Although it only encompasses 0.82% of the world's ocean surface, the Mediterranean Sea hosts nearly 7% of global total marine biodiversity. But this biodiversity hotspot is also a climate change hotspot and is known to be more sensitive than other oceanic basins to external forcing. Hence, recent studies assessed the likely future expansion of Red Sea fishes and the northwards migration of endemic coastal fishes in the Mediterranean Sea. However, the future distributions of planktonic organisms remain unknown.

Here we aim to test whether Mediterranean phytoplanktonic and zooplanktonic communities were to experience similar changes. The outputs of a regional coupled atmosphere-ocean model obtained under six different IPCC-SRES climatic scenarios were used to force several species distribution models (SDM) for different phytoplankton and zooplankton species. SDM results were cross-validated and original distribution maps were validated through expert knowledge and comparisons with time series data.

Our results show a decrease in the habitat suitability regarding microphytoplankton (diatoms) and an increase in favourable climatic conditions for smaller sized cells (picophytoplankton and nanophytoplankton). Copepods characterizing the oligotrophic conditions of the Eastern Mediterranean basin were shown to expand northwards and westwards, while species affiliated to colder and more productive areas are likely to experience a shrinking of their whole habitat by the end of the 21st century. Pelagic diversity tended towards profound transformations and a homogenization across the whole basin.

Keywords: scenarios, distribution model, niche, plankton, Mediterranean

Poster presentation

Scaling up from effects at the individual level to population and ecosystem levels via stochastic population models

Botsford L.Q and Hastings A.

The effects on upper trophic level species of physical changes in the ocean are observed primarily at the individual level, yet management responses occur at the population or ecosystem level. Thus, there is a need for methods to translate the effects of potentially multiple stressors on individual vital rates into their ecosystem consequences. Because of limited life history information, straightforward simulation approaches will be limited to only some fished species. Here we present ways in which an alternative, stochastic age structured models, can translate changes in individual rates (age-dependent survival, growth, and fecundity) into their effects on: (1) mean population abundance and (2) population responses to the different frequencies of variability in future climates. We demonstrate how future population responses to the frequency content of the future ocean environment (which may itself change, e.g., through more frequent ENSOs) depend on: (a) whether inter-annual variability affects individual growth or survival, (b) the population level variable being observed (e.g., abundance, egg production, catch), (c) species longevity, and (d) the nature of the stock-recruitment relationship. Populations are more sensitive to low frequencies, and frequencies near the inverse of their generation time through an effect termed cohort resonance. Fishing increases this sensitivity, as well as the total population variance. Translating population effects to the ecosystem level requires a dramatic expansion of model complexity to include species and human interactions. Presumably structural uncertainty will diminish with the inclusion of these new relevant factors, but eventually parameter uncertainty will increase. Thus there is a need to account carefully for, and to reduce, the uncertainty in the rapidly developing ecosystem models. The differences between cohort resonance effects from variability in growth and variability in survival may provide clues regarding possible differences between the propagation of environmental signals in a bottom-up direction and a top-down direction. We demonstrate these effects with examples from salmon, cod, hake, rockfish and marine birds.

Keywords: populations, ecosystems, frequency response, age structure

Oral presentation

Macro-ecological patterns and drivers of trophic control across marine ecosystems

Boyce D.G., Frank K., Leggett B., Petrie B. and Worm B.

The relative strength and importance of consumer versus resource control within and across marine ecosystems has been intensively investigated using empirical, experimental, and theoretical approaches for over a century. This research has led to numerous interesting discoveries, yet a unified explanation for spatial and temporal differences in trophic control and the factors influencing these patterns at macro-ecological scales remain elusive. Here, we synthesize published field studies to quantitatively examine these patterns within the northern hemisphere. The reported relationship (Pearson correlation; r) between time-series of predators and prey were used as an index of consumer ($-r$) or resource ($+r$) control of ecosystem structure. Our analysis includes 150 correlations between trophically dependent species ranging from phytoplankton to whales extracted from 50 studies published since 1950. Multivariate spatial regression analysis was used to quantitatively test several leading hypotheses of the factors influencing trophic control within and across ecosystems. Consumer control was observed to attenuate through the food chain, with strong consumer control exerted at higher trophic levels and resource control exerted at the plankton level. Spatial variability in trophic control of marine ecosystems is best explained by gradients in upper ocean temperature and species richness. Systems where temperature or species richness were higher tended to exhibit strong resource control, possibly due to increased complementarity. Phytoplankton cell size, primary production, and ecosystem omnivory were also positively correlated with trophic control. We conclude that temperature and species richness are leading correlates of spatial variability in the trophic state of marine ecosystems with important implications for ecosystem stability and recovery following anthropogenic or environmental perturbations.

Keywords: trophic control, macroecology, climate change, ecology

Oral presentation

Future climate scenarios for a productive coastal planktonic food web resulted in changed microbial grazer dynamics and phenology, and decreased trophic transfer efficiency

Calbet A., Martínez R.A., Isari S., Jakobsen H.H., Sazhin A.F, Nejstgaard J.C., Berger S.A., Tait Z.S., Olmos L., Sousoni D., Bouquet J.-M., Thompson E.

We studied the effects of future climate change scenarios on plankton communities of a Norwegian fjord system using a mesocosm approach. The plankton experienced eutrophication, 3^oC temperature rise, and a lowering of 0.4 pH units (acidification). All nutrient amended (added NP or NPSi) mesocosms showed phytoplankton blooms reaching 13-16 µg chlorophyll (chl) a L⁻¹ at day 4, dominated by chain forming diatoms, while the chl a stayed below 1 µg L⁻¹ in the control mesocosms and was comparable to the surrounding fjord. After day 4 the phytoplankton decreased sharply due to nutrient limitation and intense microzooplankton grazing. Acidification and increased temperature combined together (greenhouse conditions) had contrasting effects on the phenology and bloom-dynamics of different groups of autotrophic and heterotrophic microplankton. Bacillariophyceae, Prymnesiophyceae, Cryptophyta, and *Protoperidinium* spp. showed early bloom peaks in higher temperatures and low pH. Chlorophyta, showed lower peak abundances with acidification alone, but higher with acidification and increased temperature. Dinophyceae and ciliates showed, on the other hand, lower peak abundance with increased acidification and temperature. Over time, the plankton community shifted from an autotrophic phytoplankton bloom to a more heterotrophic system in all mesocosms, especially in the control mesocosms. The heterotrophic community strongly and evenly impacted the phytoplankton in each treatment, although the groups responsible for most of the grazing varied in the different mesocosms. The major contributors to grazing in the control mesocosms were heterotrophic nanoflagellates. Ciliates had the highest grazing impact in the eutrophic mesocosms, whereas dinoflagellates dominated the grazing pressure in mesocosms with lower pH and increased temperature. In the acidified mesocosms ciliates and dinoflagellates had an overall high impact. The mass balance and the proportion of heterotrophic/autotrophic biomass along the experiment predict a shift towards a more autotrophic community and a less efficient food web when temperature, nutrients and acidification are combined in a future climate change scenario. We discuss how this may be related to lower food quality for microzooplankton under acidification and warming conditions, and to a greater response of catabolic compared to anabolic processes at higher temperatures.

Keywords: microzooplankton, phytoplankton, acidification, temperature, eutrophication, foodweb

Oral presentation

Assessing the integrated impacts of climate change and fishing on biogeography of marine species

Cheung W.W.L. and Jones M.

Ocean warming has previously been shown to cause species' range shift. However, fishing is currently the major driver of ecological changes in marine ecosystems which can potentially modify the responses of marine species to climate change. The combined impacts of climate change and fishing on future marine species distributions and biogeography globally have not been explored. To investigate the integrated impacts from climate and fishing drivers, we apply a Dynamic Bioclimate Envelope Model (DBEM) that coupled species distribution models with population model to project future changes in distributions of over 500 species of exploited fishes and invertebrates in the world. We simulated the historical (1959 – 2004) changes in species distribution driven by either (1) environmental data simulated from NOAA's Geophysical Fluid Dynamics Laboratory Earth System Model (version 2M), or (2) observed catch data from the Sea Around Us Project, or (3) both drivers. We also examined the uncertainties associated with the use of different species distribution models and initial parameterization of the population dynamic model. We expressed shifts in distribution and biogeographic patterns in terms of the rate of distribution centroid shifts, species turnover and community composition. Our results suggest that shifts in distribution and biogeographic patterns may change considerably when both climate and fishing effects are considered compared to scenarios that consider single driver only. This study highlights the need to consider multiple stressors in climate change assessment and management, and the potential to assess how much residual risk of climate change on marine biodiversity can be reduced through effective fisheries management.

Keywords: Climate change, biogeography, multiple stressors, model

Oral presentation

About the predictive potential of early life stage IBMs: an example for Atlantic cod (*Gadus morhua*) in the North Sea

Daewel U. and Schrum C.

By using a spatially-explicit Individual Based Model we examined the potential survival and growth of early life stages of Atlantic cod (*Gadus morhua*) in response to changes in the physical forcing and lower trophic level dynamics of the North Sea ecosystem. Climate variability might impact the vital rates of cod early life stages and the recruitment process in several different ways by e.g. associated changes in temperature, transport, food quantity and quality, or by changes in predator abundance. Here, we aim at disentangling the different climate impacts on early cod survival in the North Sea. Therefore, we employed a 3d interlinked model system that includes a hydrodynamic model (ECOSMO-hydrodynamics), a physiologically-based individual based model (IBM) as well as the N(utrient)P(hytoplankton)Z(ooplankton)D(etritus) model ECOSMO providing related prey fields. We will first present results from a long-term (60 years) model integration in combination with a number of specific scenario experiments. The estimated potential larval survival was statistically analysed with respect to changes in the environmental forcing and compared to observed Atlantic cod recruitment in the North Sea. The latter indicated time periods with high and periods with no correlations between estimated larval survival and recruitment. Therefore, we secondly applied a predation index to the model simulations to understand the respective roles of top-down and bottom-up processes for larval survival and Atlantic cod recruitment in the North Sea.

Spatially explicit IBMs are a helpful tool to understand how vital rates of fish early life stages change with respect to climate change, but its applicability to understand and project recruitment is unclear and depends on species and region specific trophic interactions as well as the quality of the environmental projections. Based on our results, we will discuss the potential of the method to project recruitment changes.

Keywords: spatially-explicit IBMs, cod, North Sea, recruitment

Oral presentation

Predicting climate change impacts on marine ecosystems using GCMs, laboratory experiments, and ecosystem modelling

Eddy, T.D, Cornwall C.E., Tomczak M.T. and Lotze H.K.

Predictions about the impacts of climate change on marine primary production and low trophic levels derived from global climate models (GCMs) can be employed to drive ecosystem models. Studies have used outputs from these GCMs to inform ecosystem models developed with Atlantis, Ecopath with Ecosim, and OSMOSE to make predictions about higher trophic-level and ecosystem-level responses to climate change scenarios. This bottom-up driven approach quantifies the ecosystem effects of changing primary production as it is passed through the food web. There has also been substantial research conducted about how different groups of marine organisms are predicted to respond to increasing acidity in the ocean, many of which are laboratory studies. Generally, it has been found that calcareous organisms are more susceptible to increasing ocean acidity, such as the phytoplankton group, coccolithophores. However other groups of organisms also show responses to changing ocean acidity and various aspects of an organisms' physiology may respond differently, as their mortality, production, and consumption may respond in different ways. For example, some groups of macroalgae are predicted to show increased production as a result of increasing ocean acidification. Understanding how all of these impacts of differing directions and magnitudes for various groups of species will integrate at the ecosystem level is important to make predictions about ecosystem responses to perturbations such as climate change. Additionally, many marine ecosystems will not experience these impacts in isolation from other stressors, and impacts from fisheries exploitation that have shaped marine ecosystems will continue to affect them, in combination with climate impacts. This paper will present work that has looked at how the structure, function, and resilience of a coastal, New Zealand ecosystem has changed over a fishing exploitation history of 70 years, as well as predicted effects of the individual and cumulative stressors of: fishing, ocean acidification, and climate change driven impacts on primary production. This oral paper will compare approaches that have been informed by GCM and laboratory data for climate impacts to understand how well predictions from each approach agree.

Keywords: ecosystem modelling, Ecopath, ocean acidification, fisheries

Oral presentation

A large experimental platform to study climate-change effects on freshwater ecosystems - The LakeLab

Gessner M.O., Nejtgaard J.C., Berger S.A., Engelhardt C., Casper P., Grossart H.-P., Penske A., Hintze T., Kirillin G. and Kasprzak P.

Climate-related changes in aquatic physical environments are considered as major drivers for shifts in phenology of aquatic species, distribution and productivity of phytoplankton and zooplankton, and are expected to strongly affect ecosystem services. However, data on the ecosystem resilience to climate changes are still limited in both marine and freshwater systems. A powerful tool to document biogeochemical responses to changes in the physical environment, and to understand the underlying mechanisms is to conduct empirical ecosystem-scale manipulations using large water enclosures, also known as mesocosms. Depending on the size of the mesocosms and duration of the experiment, such experiments may capture most of the complexity of natural aquatic systems as they combine the power of replicated manipulative experiments with a high level of realism. However, a common limitation to date has been to combine large volumes with high replication, sampling frequency and advanced analysis.

To effectively meet these demands and effectively assess responses of aquatic biodiversity and biogeochemical processes to climate change under experimental conditions in lake ecosystems, a large enclosure facility was recently built in Lake Stechlin 80 km north of Berlin, Germany. Lake Stechlin and the facility offers a natural shoreline with low human development in the catchment, available long-term data sets for many physical, chemical and biological variables, and direct proximity to a well-equipped laboratory (including electron microscope, and modern molecular, flow-cytometric and biogeochemistry analytical instrumentation) and dormitory. This greatly facilitates logistics. The LakeLab consists of 24 cylindrical enclosures arranged in four blocks, facilitating varied experimental designs and simultaneous manipulation of at least two experimental factors. Each cylinder is 9 m in diameter and extends from the water surface into the sediment in about 20 m depth, thus enclosing a water volume of 1250 m³ each, or 30,000 m³ in total. An additional central mesocosm, 30 m in diameter, serves as a water reservoir. Other key features are thermoinsulating curtains in the upper 12 m of the cylinders (typical summer mixing depth = 6 to 10 m), a pumping system permitting selective withdrawal and release of water at any desired depth to manipulate stratification and mixing regimes, sediment traps, and computer-controlled profilers that take depth profiles of O₂, pH, turbidity, conductivity, PAR, pressure, temp and chlorophyll fluorescence and plant pigment composition (bbb Moldaenke probes) simultaneously in all units plus replicated profiles outside the systems in the lake for comparisons.

The facility is conceived to serve as an open experimental platform for national and international cooperation aimed at a comprehensive assessment of lake ecosystem responses to climate change. Further, since many processes in the estuarine and open marine environment have systematic similarities and direct and indirect connections with fresh water systems, that presently are little studied, the presenters wish to take the opportunity of the IMBER meeting to further discuss interests and possibilities to develop worldwide networks of such experimental facilities from the mountains to the oceans.

Keywords: International mesocosm facility, climate change, lake
Poster presentation

Impact of climate change on lower trophic levels in the Barents Sea

Hjøllo S.S, Skaret G., Dalpadado P., Skogen M. and Strand E.

The Barents Sea is an area where strong climate changes are expected to occur, and since the area is also intensively exploited commercially, it is of particular interest to predict how primary and secondary producers which transfer energy to higher trophic levels will be affected. We study the impact of climate change on Barents Sea ecosystem using the end-to-end model *norwecom.e2e*; a model system that simulate the life history of selected species through individual-based modules (in this study *Calanus finmarchicus*) two-way linked to a coupled biogeochemical and ocean circulation model. Using the 20C3M control run and the A1B emission scenario, a downscaling of the GISS-AOM global climate model has been used to force the ecosystem model for a reference (1981-2000) and a future climate (2046-2065) simulation respectively. The predicted annual primary production under the future climate scenario was on average $106 \text{ g C m}^{-2} \text{ y}^{-1}$ implying a 36 % increase from the reference scenario. *C. finmarchicus* production also increased, but less (23 %) and largely in southern and western areas where production was already high under the reference climate scenario. As a consequence, the proportion of the Barents Sea assumed to have *C. finmarchicus* concentrations high enough to sustain fish larval growth did not increase substantially. The results suggest that *C. finmarchicus* most likely are unable to take full advantage of the predicted increased Barents Sea primary production in the future, possibly due to too low temperature and because the development and spawning of *C. finmarchicus* does not match with the early primary production peak in Arctic waters. The proportion of *C. finmarchicus* with local overwintering and reproduction in the Barents Sea versus those advected in from the Norwegian Sea remained unchanged at ~75%.

Keywords: Barents Sea, Calanus, IMB modeling

Oral presentation

A social-ecological model of climate change impacts on marine ecosystems: Integrating experimental results and ecosystem service uses

Koenigstein S.

Various physiological stressors connected to climate change are anticipated to impact marine ecosystems and influence food webs, biodiversity and living marine resources. The Norwegian and Barents Seas are expected to be among the first ecosystems to be significantly impacted by ocean warming and ocean acidification, but overall impacts on ecosystems and the consequences for ecosystem services are far from clear. To advance our ecological understanding, improve projections about the adaptive capacity of the ecosystem and develop better management strategies, it is necessary to improve the integration of experimental data into modelling studies and incorporate results on individual stress sensitivities in different life stages and possible population adaptations, potential shifts in species distribution and interactions, as well as feedbacks and buffers in food web structure.

We develop a social-ecological model to synthesise the impacts of multiple stressors (increasing temperature, acidification, hypoxia) on the marine ecosystems of the Norwegian Sea and the Barents Sea, and investigate how these impacts interact with the pressure from human use and the extraction of living resources. We integrate data from physiological experiments, mesocosm community experiments and more detailed biogeochemical and primary productivity models produced within the project BIOACID (Biological Impacts of Ocean Acidification, phase 2). Impacts on fish recruitment are being incorporated via physiological and genetic results from laboratory experiments under multiple stressors with different life stages of Atlantic cod, Herring and Polar cod, and changes in food web interactions are incorporated via food energy content and behavioural experiments.

The results of these approaches are integrated into a system dynamics framework in a participatory modelling approach, focusing on the relevant ecosystem services in the target region. In personal interviews and a workshop with affected stakeholders and experts in Norway, the model framework was developed, including quantitative indicators for the ecosystem services fisheries provision, tourism and recreation, biodiversity, and carbon uptake.

We present the developed model structure and some preliminary results pointing to determinants for social-ecological systems dynamics. Changes in certain food web elements appear to be decisive for impacts on fisheries and marine-based tourism (e.g. sports fishing and whale watching), and are primarily modulated by changes in fish larval survival and food composition observed under ocean warming and acidification. This work yields insights for the integration of results across biological levels and the use of mechanistic process knowledge from physiology, population genetics and community-level experiments.

The final model will increase the understanding about the links between ocean change scenarios and their socio-economic relevance from a systems perspective. With this model, we integrate different research approaches, fill gaps between existing models and create a practical tool for an integrated ecosystem-based management of climate change impacts on fisheries and other ecosystem services, which can be used to explain mechanisms and interactions and to develop societal adaptation strategies.

Keywords: ocean acidification, model, Norway, ecosystem management

Poster presentation

Turbulence enhances feeding of larval cod at low prey densities

Kristiansen T., Vollset K.W., Sundby S. and Vikebø F.

The ability of larval fish to successfully find food after hatching is critical for their growth and survival during the early life stages. However, the feeding ecology of larval fish is strongly dependent on prevailing physical and biological conditions. Small changes in the prey distribution, turbulence, light, and ocean temperature can affect larval survival probabilities. This study combined physical and biological observations collected from Atlantic cod (*Gadus morhua*) spawning grounds from Lofoten, Norway during the years 1991-1992 with an individual-based model (IBM) that is able to simulate behavior, feeding, and growth. Observational data on the vertical distribution of larval cod revealed that they congregated at 10-25 m during the day, although the highest abundance of prey was generally in the upper 10 m. Using the behavioral component of the IBM, we analyzed the mechanistic interactions between larval bioenergetics and the physical-biological environment and compared modeled and observed vertical larval cod distribution. During periods of both low and high prey densities, turbulence had a significant impact on larval cod feeding and growth rates as well as larval vertical distribution. At very low prey abundance (<5 nauplii L^{-1}), turbulence enhanced encounter rates were very important for sustaining ingestion and growth rates for first feeding larval cod. Our results suggest that turbulence allowed larval cod to sustain high ingestion rates even deeper in the water column, where prey densities are usually lower.

Keywords: individual-based model, behavior, turbulence, encounter, trade-off

Poster presentation

Climate change impacts on global pelagic communities

Lefort S., Aumont O., Bopp L., Gehlen M. and Maury O.

Temperature, oxygen and food availability directly affect marine life. Climate models forecast a global warming of the surface ocean ($\sim +3^{\circ}\text{C}$), a de-oxygenation of the subsurface ocean ($\sim -3\%$) and a decrease of net primary production ($\sim -8\%$). We estimated the effects of these changes on marine communities using a coupled biogeochemical (PISCES) - high trophic level (APECOSM) model embedded in the last generation of the IPSL-CM5A-LR Earth System Model that ran from 1850 to 2100 under the new “business as usual” carbon emission scenario (RCP8.5) provided by the IPCC. The APECOSM model is a size-structured bio-energetic model based on the dynamic energy budget theory (DEB). It includes size-structured trophic interactions and mechanistic parameterization of environmentally driven behavioural movements. It simulates the three dimensional dynamic distribution of three interactive pelagic communities under the effects of multiple environmental factors. Our RCP8.5 simulation highlights significant changes in the spatial distribution, biomass and size-spectrum of the pelagic communities. The biomass and maximum body-size of the pelagic communities increase at high latitude over the course of the century, while they strongly decrease at low- and mid-latitude because of the reduction of resource availability. The model projects that, at low- and mid-latitude, the decline of large body-size organisms exacerbates the pelagic biomass decrease. On the other hand, small body-size organisms are predicted to balance their metabolic needs and might therefore be more resilient to climate change.

Keywords: climate change, pelagic community, size-based model

Oral presentation

Variability of primary production in the Okhotsk Sea and its correspondence to the hydro-dynamic processes

Lobanova P.

A problem of primary production distribution in different dynamic formations in the world's oceans is important both for hydro-biological positions and for fishery applications. Estimation of primary production on base of remote sensing measurements opens new possibilities of describing and explaining the source mechanisms of high-productive areas in the oceans, information of which has been very limited until recently.

The research focuses on sea current and primary production flows variability in the Okhotsk Sea in 2002 – 2012 based on satellite altimetry and biotic (primary production) data. We estimated an average annual and seasonal rate of sea level and primary production increase/decrease, identified and compared dynamic and biotic fronts. Close connection between them was found in some dynamic formations in the south of the sea. We calculated the divergence of primary production flows showing that in the south of the Okhotsk Sea divergence zones alternated with areas of convergence which is likely due to occurrence of gradient-vortex waves.

Keywords: primery production, hydro-dinamic and biotic fronts

Poster presentation

Trophic ecology and bioenergetics of a planktonic predator jellyfish, *Pelagia noctiluca*.

Milisenda G., Bandelj V., Fuentes V., Solidoro C., Boero F. and Piraino S.

Studies of trophic relationships are central to the mechanistic understanding of ecosystems as they shed light both on the foraging ecology of individual species and on general paths of transfer of energy and organic matter through the food web. Carnivorous jellyfish are mainly subject to bottom-up controls from their forage base rather than to top-down controls from predators, suggesting that information on what they eat, how much they eat, and where they eat is essential to establishing their eco-physiological optima and the biological phenotypic traits fostering their massive occurrence. This is of particular importance for taxa with known potential impact on coastal ecosystems and human activities, such as jellyfish. Here we used a combination of methods (gut contents, stable isotope and fatty acid analyses) to trace the dietary sources of the mauve stinger *Pelagia noctiluca*, the predominant jellyfish species in the western and central Mediterranean Sea, to clarify its predatory trophic impact on the coastal marine food webs over the year, by elucidating potential dietary preferences in relation to seasonal shifts of prey availability. A bioenergetic individual-based model has been also developed and successfully validated against a 1 year-long field data set of the average size in a cohort, in order to predict variation in the size of *P. noctiluca* and the impacts of seasonal blooms on the overall planktonic community.

Keywords: Isotopes; Fatty-Acids; IBM; Gut-Contents; Trophic-Biomarkers; Physiology

Oral presentation

Impacts of climate variability on recruitment in an Arctic seabird population

Myksvoll M.S., Erikstad K.E., Barrett R.T., Sandvik H. and Vikebø F.

Climate variability influences seabird population dynamics in several ways including access to prey near colonies during the critical chick-rearing period. This study addresses breeding success in a Barents Sea colony of common guillemots *Uria aalge* where trophic conditions vary according to changes in the northward transport of warm Atlantic Water. A drift model was used to simulate annual variations in transport of cod *Gadus morhua* larvae along the Norwegian coast towards their nursery grounds in the Barents Sea. The results showed that the arrival of cod larvae from southern spawning grounds had a major effect on the size of common guillemot chicks at fledging. Furthermore, the fraction of larvae from the south was positively correlated to the inflow of Atlantic Water into the Barents Sea thus clearly demonstrating the mechanisms by which climate-driven bottom-up processes influence interannual variations in reproductive success in a marine top predator.

Keywords: cod larval, Atlantic Water, common guillemot

Oral presentation

How can increased temperature affect the dynamics of the Barents Sea food web?

Planque B., Lindstrøm U. and Subbey S.

There is currently much concern over the possible effects of future ocean warming on the spatial distribution, phenology, productivity or even survival of individual marine species. Studies conducted on individual marine species are sometimes raised to community or ecosystem level, but this is a difficult task given that individual species will respond simultaneously to changes in temperature conditions and to changes in other species dynamics, thereby creating intricate feedbacks and complex dynamics. To examine the potential effects of temperature increase on food webs requires that the dynamics of multiple species and their interactions be considered simultaneously. In the present study, we investigate how the Barents Sea food web dynamics may respond to ocean warming by combining two complementary approaches. Firstly, we use a non-deterministic network dynamics model (NDND) as a reference for the variability of the Barents Sea food web dynamics. This model does not explicitly require deterministic functions to describe population dynamics or trophic interactions. Instead, it uses coefficients that describe the thermodynamical and physiological limits of populations. Secondly, we use the metabolic theory of ecology (MTE) to derive some key parameters for the NDND model and define how these can vary under warming scenarios. We model how increased temperature can modify assimilation and metabolic efficiencies. We compare food web emergent properties, such as temporal autocorrelation in biomass time series, functional responses (biomass transfer) or integrated diet fractions under various temperature scenarios.

Keywords: warming, foodweb dynamics, Barents Sea, model

Oral presentation

Regional responses of marine environment and fisheries resources in the East/Japan Sea related to climate-ocean forcing

Rahman S.M.M., Jung H.K., Kang C.-K. and Lee C.I.

This study aimed to identify the long-term fluctuation pattern in wintertime local environmental parameters (e.g. sea water temperature) for the northern part of the East/Japan Sea (NES) and the southern part of the East/Japan Sea (SES). Variations related to major Climate Regime Shifts (CRS) in 1976/77, 1988/89 and 1998 were detected, and tried to identify regional differences for the common climate forcing phenomena. Results suggest that Arctic Oscillation (AO), Aleutian Low Pressure (ALP), Siberian High Pressure (SHP) and East Asian Winter Monsoon (EAWM) have direct influence on the surface sea water temperature (10-200m, SWT), upper layer density profile (10-200 m, DP) and stratification index (SI) in both regions of the East/Japan Sea whereas influence of Pacific Decadal Oscillation (PDO) has different patterns. In the NES region, PDO exerts direct influence to SWT, DP and SI whereas in the SES region, both of direct and lag influences were identified. For direct climate forcing, surface wind have greater impact in both of the regions. For lag climate forcing, SWT anomaly has been detected which is linked to the volume transport pattern between Kuroshio Current (KC) and Tsushima Warm Current (TSWC). Fluctuation of major commercial fishery in this sea, specifically of walleye pollock and common squid have significant correlation with the stratification index in winter and consequently on the productivity of these regions.

Keywords: East/Japan Sea, climate forcing, stratification, fisheries

Poster presentation

Modelling the combined effects of ocean acidification, climate change and oil related discharges on the northern shrimp *Pandalus borealis*

Ravagnan E., Arnberg M. and Bechmann R.

Ocean acidification (OA) will be one of the most serious threats to the marine environment in the future; furthermore reduced ice cover in the Arctic caused by on-going climate change will lead to increased transport by ships and hence increased risk of accidental oil spills. For this reason it is important to study the combined effects of multiple stressors on selected marine species.

Experiments have been performed in the laboratory to study effects of ocean acidification (OA) in combination with other types of anthropogenic stress (oil exposure) on fitness and physiology of adults and early life stages of the northern shrimp *Pandalus borealis*, an ecologically and economically important organism in the marine ecosystem. Data from experiments and literature are used in an individual-based model to study the single and combined effects on different life-stages of *P. borealis*.

Individual-based models are simulations of the global consequences that result from the local interactions of members of a population. These models, exploring how individuals behave and interact with each other and their environment (through the definition of a series of procedural rules and characteristic parameters), provide a valuable way to study the mechanisms through which population and ecosystem interrelate.

Firstly, the shrimp at various life stage are implemented in the model as unaffected, to establish the model baseline; secondly, the procedural rules of individuals are modified according to the results obtained in the laboratory (supplemented by literature information) to study changes in survival and growth under combined effects. Stochasticity is added to allow individual variability.

The models are implemented with NetLogo, a programmable modelling environment for simulating natural and social phenomena, freely distributed. The possibility to change parameters affecting the individuals in real time allows the study of multiple simulated scenarios.

Keywords: Combined effects, northern shrimp

Oral presentation

Reproduction and growth of the suboxic tolerant bearded goby on the Namibian shelf of Benguela

Salvanes A.G.V., Seivåg M.L., Taha Y., Christiansen H., Kjesbu O., Folkvord A., Utne-Palm A.C., Ekau W. and van der Plaz A

One of the endemic fish species off Namibia, the numerous bearded goby, *Sufflogobius bibarbatus*, is a major prey for large commercial fish populations. Following the decline of clupeid populations in the late 1960s, and their subsequent collapse in the 1980s, higher trophic predators off Namibia have been increasingly supported by the bearded goby prey. Previous work has shown that this fish species can cope better with low oxygen levels than other species, but also that distribution tends to vary with changes in available oxygen. Its main distributional area coincides with that area of the Namibian shelf where sea-bed oxygen levels are $<1 \text{ ml O}_2 \text{ L}^{-1}$ [$43.5 \mu\text{mol kg}^{-1}$]. Unlike their predators, these fish can remain alert in complete suboxia and can cope with gradual changes in oxygen concentrations as well as with sulphide shocks. Despite its importance of the northern Benguela ecosystem, yet very little is known on its recruitment biology. Here we report empirical data on variation in maturation, growth and male reproductive tactics. Both sexes matured and reproduced at oxygen levels $< 0.5 \text{ ml/L}$, low oxygen stood out as a limiting factor for growth and reproduction. A spawning area was indicated on outer central shelf. Females were smaller and grew slower than males, with an average relative fecundity, including recruiting oocytes, of 1600 g^{-1} . The two male reproductive tactics also differed in age, size and growth. The sneakers were smaller and younger than the territorials. The findings are discussed in view of environmental variation.

Keywords: reproduction, growth, bearded goby, Benguela

Poster presentation

Spatial dynamics of the bearded goby and its key fish predators off Namibia varies with climate and oxygen availability

Salvanes A.G.V., Bartholomae C., Yemane D., Gibbons M.J., Kainge P., Krakstad J.-O., Rouault M. Staby A. and Sundby S.

Hypoxia ($O_2 < 2.0 \text{ ml L}^{-1}$ [$87 \mu\text{mol kg}^{-1}$]) and severely hypoxic water masses ($O_2 < 0.5 \text{ ml L}^{-1}$ [$21.8 \mu\text{mol kg}^{-1}$]) are increasing in coastal marine ecosystems due to eutrophication and warming. Here, we investigate the response of the suboxic-tolerant endemic fish, *Sufflogobius bibarbatus*, to variations in the thermal and oxygen environment, as well as to predation pressure, using 22 years' worth of satellite and in-situ data. We show that environmental variation and predation pressure affect the goby population, which has expanded over the last decade while that of horse mackerel has contracted. These changes co-occurred with a general warming in the north and central shelf areas (north of 24.5 OS). Spring warming positively affected both goby and hake abundances, but not the horse mackerel, suggesting different responses to surface temperature. The goby habitat contracted when predators were abundant, particularly in the north which is the fringe of its distributional area. The implications of the differential tolerance of gobies and their predators for climate variations are discussed.

Keywords: *Sufflogobius bibarbatus*, predators, hypoxia, environmental variation

Oral presentation

MERMEX project, objectives and first results

Durrieu de Madron X., Guieu C. Presented by Sempéré R.

The Mediterranean Sea is unique and evolves rapidly, with large inter annual to decadal variability and abrupt fluctuations. The semi-enclosed nature of the Mediterranean, together with its smaller inertia compared to large oceans, makes it more sensitive to natural variations in fluxes (between, e.g., the air and sea, freshwater and the sea) and water flows. These natural pressures interact with the trend of increasing human activities in the coastal regions, making the sea even more sensitive. Over the past century, the population along the Mediterranean coasts has expanded substantially. Urbanization, industrialization and touristic exploitation (with associated impacts as land use change, increased demand for food and water, waste disposal, coastal erosion, etc.), intensive agriculture and aquaculture, riverine and atmospheric inputs and overfishing have exerted progressively growing pressure on the Mediterranean environment, putting their integrity at stake. Most of the Research objectives of International MERMEX and indicated below and were deduced from the MERMEX article (MERMEX group, 2011. Marine Ecosystems Responses to climatic and anthropogenic forcings in the Mediterranean. Progress in Oceanography (91): 97-166), in which ~100 co-authors presented current knowledge on biogeochemistry in the Mediterranean Sea and highlighted the uncertainty on the responses to global change in the 21th Century.

- Impact of stratification and destratification mechanisms and in the overall thermohaline circulation on the spatio-temporal distribution of nutrients and their budgets?
- How would likely changes in nutrient inputs from physical transport, rivers, the atmosphere (including extreme events) and straits affect the nutrient availability in the photic layer of the Mediterranean Sea, the relative abundance of primary producers, and the higher trophic levels?
- What are the typical concentrations of chemical contaminants in the various water masses of the Mediterranean? What are their sources and sinks (e.g., atmosphere versus rivers, especially for organic contaminants) and seasonal variations?
- What is the role of the land-sea boundary (rivers, large cities, groundwater discharge) in the material balance of the Mediterranean Sea (carbon, nutrient, contaminants) ?
- Will changes in the frequency or magnitude of extreme events lead to the dispersion or dilution of carbon, nutrients, and pollutants or, in contrast, to their accumulation in specific compartments?
- What will be the impact of changes in light radiation on biogeochemical processes, including primary production, POC- degradation processes, and degradation of DOM and pollutants?
- What is the actual rate of change of both temperature and pH in the Mediterranean Sea? How will these variables evolve and impact the Mediterranean solubility pump? What impacts will they have on the functioning of pelagic and benthic Mediterranean ecosystems?
- Will the functioning of mesopelagic and deep sea Mediterranean ecosystems be strongly affected by global change?
- As the surface seawater warms, will the planktonic community of the pelagic ecosystem

Session C3: Impact of climate change

become dominated by nanophytoplankton and jellyfish, as suggested by several recent studies?

First results in northwestern Mediterranean Sea and future research in the global basin will be presented.

Keywords: Mediterranean Sea, global change

Poster presentation

Synthesis: Climate effects on biodiversity, abundance and distribution of marine organisms in the Benguela

Jarre A., Hutchings L., Kirkman S.P., Kreiner A., Tchupalanga P., Kainge, P., Uanivi U., Van der Plas A., Blamey L.K., Coetzee J., Lamont T., Samaai, T., Verheye H.M., Yemane D., Axelsen, B.E., Ostrowski M., Stenevik E.K. and Loeng H. Presented by Shannon L.

The NansClim project (2010-2013) represented a regional collaboration on climate effects on Benguela dynamics, undertaken in three task groups (oceanography, pelagic and demersal). This synthesis highlights the findings and explores their potential implications for ecosystem-based management. The Angolan subtropical waters and the northern Benguela have been warming since the early 1990s. The South Atlantic High Pressure Cell has shifted southwards. The southern Benguela off Namaqualand north of Hondeklip Bay has likewise warmed. Upwelling variability has increased in the remaining parts of the southern Benguela. Multi-annual and decadal variability is evident in time series of oxygen and phytoplankton biomass, while zooplankton and fish communities have changed substantially. Changes in the pelagic communities include altered structure in the three southern subsystems, decreased yields in the northern Benguela, and distributional shifts in the south. Hotspots of demersal biodiversity are identified. Demersal communities have shifted northwards and deeper in the upwelling region, and southwards and deeper in the Angolan subtropical system. An ecosystem regime shift has been documented for both the northern and the southern Benguela in the mid-1990s. Fishing has been at least as important a driver of long-term ecosystem change as climate variability. Shifts towards smaller and/or younger fish are expected to decrease ecosystem resilience to warming. To document ecosystem changes an improved balance between fisheries resource surveys, biodiversity assessments and environmental monitoring needs to be established. Possible changes in species distribution and in the boundaries of the four subsystems require continued regional collaboration and improved co-ordination of research efforts.

Keywords: Climate variability & change, EAF, SE Atlantic

Oral presentation

Session D1: Marine environmental status and biodiversity: from structure to functionality, delivering ecosystem services

Oral presentations

Tuesday 24 June, 11:00-12:30 Parallel session 1

Topic: Theory and Policy

Chairs: Angel Borja and Alice Newton

Room K4

Time	Presenter	Title
11:00-11:30	Borja, Angel	Good Environmental Status of marine ecosystems: What is it and how do we know when we have attained it?
11:30-11:45	Heiskanen, Anna-Stiina	Conceptual framework to assess the state of marine ecosystem services
11:45-12:00	Pinto, Rute	Linking biodiversity indicators, ecosystem functioning, provision of services and human well-being in estuarine systems: Application of a conceptual framework
12:00-12:15	Lotze, Heike	Ecosystem effects of exploitation
12:15-12:30	All	General Discussion

Tuesday 24 June, 14:00-15:30 Parallel session 2

Topic: Marine Strategy Framework Directive

Chairs: Angel Borja and Alice Newton

Room K4

Time	Presenter	Title
14:00-14:30	Elliott, Mike	How will climate change affect our ability to meet Good Environmental Status for marine biodiversity?
14:30-14:45	Luisetti, Tiziana	The European Marine Strategy Framework Directive: barriers to its implementation
14:45-15:00	Patricio, Joana	Monitoring networks currently used in European seas: Is the marine monitoring for the Marine Strategy Framework Directive fit-for-purpose?
15:00-15:15	Coll, Marta	Prioritizing biodiversity and conservation-based indicators in a comparative framework to evaluate the exploitation status of marine ecosystems
15:15-15:30	Strong, James	The role of biodiversity in marine ecosystem functioning and their relevance to the implementation of the Marine Strategy Framework Directive, its monitoring, modelling and management

Session D1: Marine environmental status and biodiversity

Tuesday 24 June, 16:00-17:30 Parallel session 3

Topic: Tools and Assessment

Chairs: Angel Borja and Alice Newton

Room K4

Time	Presenter	Title
16:00-16:30	Heiskanen, Anna-Stiina	Biodiversity indicator inventory - a catalogue software and a review of the current indicator set
16:30-16:45	Robson, Laura	Developing indicators to meet European policy requirements: How to assess the health of benthic habitats?
16:45-17:00	Torn, Kaire	Tool for assessing status of marine and coastal biodiversity on the example of Gulf of Riga, NE Baltic Sea.
17:00-17:15	Certain, Gregoire	Integrated Biodiversity Assessment in the Barents Sea
17:15-17:30	Gogina, Mayya	Holistic approach to analyze benthic fauna communities on the whole Baltic Sea

Wednesday 25 June, 11:00-12:30 Parallel session 4

Topic: Pressures and Regional studies

Chairs: Angel Borja and Alice Newton

Room K4

Time	Presenter	Title
11:00-11:30	Newton, Alice	Exploring links from Eutrophication to Biodiversity: two descriptors accessing the good environmental status of the European seas
11:30-11:50	Martin, Georg	Looking for measure of the status of marine biodiversity along the gradient of cumulative human pressure, case study from northern Gulf of Riga, the Baltic Sea
11:50-12:10	Reygondeau, Gabriel	Ecological Geography of the Mediterranean Sea
12:10-12:30	David, Niv	Regional extinctions and invaders' domination: an ecosystem phase-shift of Levant reefs

Session D1: Marine environmental status and biodiversity

Wednesday 25 June, 14:00-15:30 Parallel session 5

Topic: Space and time

Chairs: Angel Borja and Alice Newton

Room K4

Time	Presenter	Title
14:00-14:15	Louzao, Maite	Spatial overlap of key conservation areas for marine predators and human pressures in southern European waters management strategies
14:15-14:30	Herkül, Kristjan	Assessing the spatial patterns of marine benthic biodiversity using remote sensing and predictive modeling
14:30-14:45	Rynearson, Tatiana	Biodiversity in the plankton: are ecosystem services influenced by evolutionary mechanisms?
14:45-15:00	Cheung, William	Biodiversity change in the 21 st century
15:00-15:15	Chaalali, Aurélie	How will climate-induced primary production changes affect the overall food-web functioning of a highly exploited ecosystem?
15:15-15:30	Lekang, Katrine	High through-put molecular methods in environmental monitoring: sample preparation and analytical pipelines

Poster presentations

Tuesday 24 June, 17:30 Poster Session 1

ID	Presenter	Title
D1.P1	Coll, Marta	Disentangling the relative importance of environmental and human drivers on the spatial distribution of marine biodiversity in the NW Mediterranean Sea
D1.P2	Coll, Marta	Trophic dynamics of the pelagic ecosystem of the NW Mediterranean Sea: new insights considering ontogeny and season
D1.P3	Chiba, Sanae	Zooplankton and phytoplankton diversity, trophic link and spatial heterogeneity - a study based on the North Pacific CPR Survey

Good Environmental Status of marine ecosystems: What is it and how do we know when we have attained it?

Borja A., Elliott M., Andersen J.H, Cardoso A.C., Carstensen J., Ferreira J.G., Heiskanen A.-S., Marques J.C., Neto J., Teixeira H., Uusitalo L., Uyarra M.C. and Zampoukas N.

The European Marine Strategy Framework Directive (MSFD) requires EU Member States (MS) to achieve Good Environmental Status (GEnS) of their seas by 2020. We address the question of what GEnS entails especially with regard to the level at which targets are set (descriptors, criteria, indicators), to scales for assessments (regional, sub-divisions, site-specific), and to difficulties in putting into practice the GEnS concept. We propose the next refined and operational definition of GEnS, indicating the data and information needed to all parts of that definition: “GEnS is achieved when physico-chemical (including contaminants, litter and noise) and hydrographical conditions are maintained at a level where the structuring components of the ecosystem are present and functioning, enabling the system to be resistant (ability to withstand stress) and resilient (ability to recover after a stressor) to harmful effects of human pressures/activities/impacts, where they maintain and provide the ecosystem services that deliver societal benefits in a sustainable way (i.e. that pressures associated with uses cumulatively do not hinder the ecosystem components in order to retain their natural diversity, productivity and dynamic ecological processes, and where recovery is rapid and sustained if a use ceases)”. We indicate the options for determining when GEnS has been met, acknowledge the data and information needs for each option, and recommend a combination of existing quantitative targets and expert judgement. We think that the MSFD implementation needs to be less complex than shown for other similar directives, can be based largely on existing data and can be centred on the activities of the Regional Seas Conventions.

Keywords: Assessment; descriptors; indicators; integration; MSFD

Oral presentation

Integrated Biodiversity Assessment in the Barents Sea

Certain G. and Planque B.

Biodiversity has become a major political, ecological and conservation topic, from the Rio conference in 1992, which led to the Convention on Biological Diversity (CBD), to the recent creation of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Marine surveys, in which large amounts of data on the distribution and abundance of species are collected, constitute a valuable source of data for the evaluation of marine biodiversity. Species abundance in a sample taken from a trawl, grab or net classically present a right-skewed pattern, i.e. few species being abundant and many species being found in small quantities. This pattern is known as the Species-Abundance Distribution, and its main characteristics can be summarized through biodiversity measures. Using such measures, it is possible to partition biodiversity into local (α -diversity) and spatio-temporal (β -diversity) components. In its simplest form, diversity partitioning separates the diversity existing within samples (e.g. trawl hauls) from the diversity due to differences between samples (e.g. in distinct geographical locations or time periods). Such partitioning provides a baseline against which newly collected data can be interpreted. It is also possible to partition diversity successively at different scales of space, time, habitat, or any other sample classification relevant for the system under study. We apply this approach, known as hierarchical biodiversity partitioning, on data collected during oceanic surveys to provide an integrated assessment of the biodiversity of the Barents Sea. Each summer since 2004, the Barents Sea area (1.6 km²) has been sampled by 6 survey vessels operating simultaneously. Between 2004 and 2012, 3831 bottom trawls and 2739 pelagic trawls have been carried out, providing information on 158 and 110 taxa, respectively. The integrated diversity assessment quantifies species diversity and turnover rates over distinct geographical regions of the Barents Sea. It constitutes a biodiversity baseline against which data collected in the future can be compared in order to statistically evaluate possible changes in biodiversity in different regions of the Barents Sea.

Keywords: Biodiversity baseline, Hierarchical partitioning, Barents Sea

Oral presentation

How will climate-induced primary production changes affect the overall food-web functioning of a highly exploited ecosystem?

Chaalali A., Bopp L., Lassalle G., Saint-Béat B. and Niquil N.

The Bay of the Biscay is a macro-ecosystem historically exploited by fisheries. As other coastal systems, it is both submitted to strong anthropogenic and climatic pressures which may induce severe alterations of the trophic food web functioning. An Ecopath model, usually set up for the implementation and evaluation of ecosystem-based fisheries management strategies, was already built in order to apprehend the energy fluxes within the food web of the Bay of Biscay. However, it did not allow to assess the evolution of the Bay of Biscay' trophic state in a context of climate changes. In this study, we used a holistic statistical modeling method, i.e. linear inverse model based on a Monte Carlo-Markov Chain approach (LIM-MCMC), derived from this Ecopath model. Our main goal was to characterize via a sensitivity analysis of this LIM-MCMC model, the climate-induced alterations on the primary production that may propagate through the entire trophic food web. We based our analyses on simulations performed with earth-system models forced by IPCC-type scenarios and discuss how anthropogenic climate change will modify the ecosystem food web properties characterized using Ecological Network Analysis (ENA, e.g. recycling, omnivory, trophic efficiency). The coupling of LIM-MCMC with ENA allowed to use statistical comparisons of food web properties.

Keywords: climate changes, food-web properties, primary production

Oral presentation

Biodiversity change in the 21st century

Krug C., Cheung W. and Leadley P.

Global environmental change has considerable impacts on biodiversity and ecosystems. Species abundances and distributions are changing due to local extinctions and range shifts, which leads to changes in ecosystem structure and function, and ultimately, ecosystem services provision. To understand these changes and their wide-ranging implications, it is necessary to track the responses of species, communities and ecosystems, to identify the drivers of biodiversity change, and to pinpoint those areas that are particularly vulnerable to change. The development of effective policy in the face of global change makes it necessary to develop scenarios to anticipate future biodiversity change.

The bioDISCOVERY, a core project of DIVERSITAS (www.diversitas-international.org/activities/research/biodiscovery), aims to improve monitoring, assessment and projections of biodiversity under global change. To achieve these, scientists from different disciplines collaborate in a number of projects and implementing activities. The results are disseminated to relevant stakeholders, policy- and decision-makers as well as political institutions at national and international levels. Four programs under bioDISCOVERY are presented here:

TRY: Refining (plant) functional trait classifications for Earth System Modelling. The TRY initiative (www.try-db.org) is a global network of vegetation scientists aiming to construct a global database of plant functional traits. This database is available to the ecological community, allowing for insights into how plant functional traits are linked to ecosystem function. The data are also used to support the design of a new generation of global vegetation models. The database is envisaged to eventually become a truly global trait database that includes organisms across the terrestrial, freshwater and marine realms.

Genetic basis of species response to climate change. Phenological shifts have been observed in a number of species as a response to climate change. The genetic basis and its contribution to species' adaptation to climate change are unclear. The EcoEvol initiative jointly organised with bioGENESIS, addresses questions concerning the response of species and ecosystems to climate change, and to contribute to the development or improvement of models that account for both evolutionary and functional processes.

Harmonising Global Biodiversity Models. The main objective of this EU COST Action (www.harmbio.eu) is the harmonization of current models and datasets of terrestrial, freshwater and marine biodiversity to improve the reliability of future projections of biodiversity change under various policy options for environmental decision making.

Biodiversity Futures: Scenario Development and Assessment. Combining the expertise and advances of the various bioDISCOVERY activities allows for the development of scientifically sound scenarios and projections of biodiversity changes in response to current and future environmental change. The program contributed to Global Biodiversity Outlook 3 assessment what was a synthesis and critical analysis of existing global and regional biodiversity scenarios. Key findings include the identification of a number of ecosystem tipping points that are driven by climate. For the Global Biodiversity Outlook 4, an in-depth biodiversity scenario analysis to determine the progress towards the Aichi Biodiversity

Session D1: Marine environmental status and biodiversity

Targets is currently being conducted, with marine systems highlighted in three of the Targets (Incentives, Sustainable Fisheries and Vulnerable Ecosystems).

Keywords: Biodiversity, global change, traits, adaptation, assessment

Oral presentation

Zooplankton and phytoplankton diversity, trophic link and spatial heterogeneity – a study based on the North Pacific CPR Survey

Chiba S., Batten S., and Yoshiki T.

Lower trophic level diversity is widely considered a useful indicator of marine ecosystem health, and regional to global distribution and temporal variation of plankton species diversity have been studied with environmental factors such as SST. However, estimated biodiversity value is subject to vary depending on the spatial and temporal scales due to heterogeneity of plankton distribution. This is particularly important in evaluating role of plankton diversity for higher trophic level productivity as each fish species has its own crucial spatio-temporal windows for various lifecycle events. This study is to investigate heterogeneity of plankton distribution and how that influences regional species diversity using samples collected by seasonal Continuous Plankton Recorder (CPR) survey for 2009-2012 in the western North Pacific (43-55°N, 140-170°E). CPR is the only observation tool that is capable to continuously collect plankton samples over hundreds of nautical miles. We analyzed species composition of zooplankton and phytoplankton every another CPR sample sheet (20 nm intervals). For all seasons, area mean diversity (H') of zooplankton and phytoplankton interannually varied in a similar manner, low in 2010 and high in 2011, indicating influence of bottom-up process induced by interannual variation in climatic-oceanic forcing. On the other hand, its relationship was out of phase for sample-to-sample comparison. Abundance of large copepods (>2.0mm) and diatoms contributed to high diversity of zooplankton and phytoplankton, respectively. As copepod community size (CCS) and diatom abundance rather showed a negative correlation; low diatom abundance was associated with dominance of large copepods, suggesting copepods grazing pressure, thus top-down process, influenced phytoplankton diversity at the smaller spatio-temporal scale. Other biotic and abiotic factors responsible for the observed spatial variation in plankton diversity will be discussed.

Keywords: Diversity, spatial heterogeneity, CPR, North Pacific

Poster presentation

Trophic dynamics of the pelagic ecosystem of the NW Mediterranean Sea: new insights considering ontogeny and season

Albo-Puigserver M., Navarro J., Coll M. and Palomera I.

Marine ecosystems in the Mediterranean Sea are fundamentally driven by their pelagic compartments. Moreover, some pelagic species such as anchovy, sardine and tuna species, are highly commercial species. However, the knowledge gathered from them is frequently scarce, impairing our capabilities to correctly manage its marine resources. We investigated the seasonal and ontogenetic changes in the trophic structure of the pelagic ecosystem of the NW Mediterranean Sea. Trophic ecology was analysed by determining the stable isotopes of carbon and nitrogen in both juvenile and adult individuals of twelve species of fish and cephalopods collected throughout the year. Community-isotopic descriptors revealed a consistency in the structure and the high importance of small pelagic as main trophic resources for pelagic and demersal predators. Overall, there were ontogenetic shifts in the trophic position of the species affecting the trophic relationships. We also found differences in the trophic niche and position between ecological similar species such some squids and medium pelagic fish. These results provided new insights in the trophic dynamics of the pelagic food webs, highlighting the importance of considering the ontogeny of species in trophic analysis and confirming the strong pelagic-demersal coupling of Mediterranean marine ecosystems. This knowledge is essential to move towards and ecosystem-based management of fisheries in the region.

Keywords: Stable-isotopes, Food-web, Pelagic-compartment, Trophic-niche, NW-Mediterranean

Poster presentation

Disentangling the relative importance of environmental and human drivers on the spatial distribution of marine biodiversity in the NW Mediterranean Sea

Navarro J., Coll M., Cardador L., Fernández Á.M. and Bellido J.M.

Identifying the factors that affect the spatial distribution of marine biodiversity is a central issue to ecology. This knowledge is crucial to evaluate biodiversity patterns, to predict the impact of environmental change and anthropogenic activities, and to design accurate management programs. In this context, we investigated the degree to which environmental features, human activities and spatial constraints interact and influence spatial gradients in marine biodiversity using the Western Mediterranean Sea as a model system. By using information obtained from extensive experimental surveys throughout the study area we examined the relative importance of environmental variables, human activities and spatial constraints on the spatial distribution of the richness, abundance, and biomass of different marine demersal groups using deviance partitioning analyses. Our results revealed that the largest fraction of variability of biodiversity metrics of most marine groups analysed here is accounted for by the joint effect of environment and human activities, environment and spatial variables or between all three groups of variables. Among pure effects, deviance partitioning results showed that the effect of environmental variables was more evident than the effect of human or spatial variables. The effect of single environmental and human variables considered in the analyses was different for different marine groups. This study contributes to the knowledge of the effects of ecological factors on the spatial distribution of marine biodiversity in the Mediterranean Sea, important in the development of more complex spatial analyses. Our results support the prediction that the joint effect of different predictor sets can be highly relevant in spatial patterns of biodiversity due to spatial collinearity. Thus, the simultaneous analysis of the relative effect of ecologically important predictor sets is important in preventing misinterpretations of the ecological mechanisms that explain spatial distribution of marine biodiversity.

Keywords: environmental-variables, human stressors, marine biodiversity, Mediterranean

Poster presentation

Prioritizing biodiversity and conservation-based indicators in a comparative framework to evaluate the exploitation status of marine ecosystems

Coll, M. and the IndiSeas project coordinators

"IndiSeas ("Indicators for the Sea") is a collaborative international working group established in 2005 that aims to evaluate the status of exploited marine ecosystems using a suite of indicators in a comparative framework. An initial suite of eight community- to ecosystem-level, data-based indicators was selected to quantify the ecological effects of fishing using several criteria such as data availability, sensitivity to fishing and public awareness. The set comprised: fish mean, length, proportion of predatory fish, mean maximum life span, trophic level of the catch, inverse fishing pressure, survey total biomass, biomass stability, and proportion under/moderately exploited species. This set was recently extended to explicitly capture the effects of fishing on biodiversity and aspects relevant to conservation in fished marine ecosystems. The stepwise selection and its rationale are presented in this contribution.

First we consider an expanded list of potential candidate biodiversity indicators and select a subset of suitable indicators based on data availability across ecosystems, ease of interpretation of the indicators in response to fishing management and specificity of indicators to fishing impacts. This subset of indicators is calculated using data from over 30 exploited marine ecosystems, and then it is examined using state and trend analyses, correlation coefficients and redundancy tests to select a final reduced set of indicators. We finally perform analyses with the total set of ecological and biodiversity indicators to assess the exploitation status of the marine ecosystems considered, taking into account specific ecosystem features, socioeconomic realities, environmental forcing, and exploitation histories.

Keywords: ecological indicators, biodiversity, conservation, fishing impacts

Oral presentation

Regional extinctions and invaders' domination: an ecosystem phase-shift of Levant reefs

Rilov G. Presented by David N.

Using past sporadic data and data from current (2009-2013) extensive surveys and a monitoring program along the entire Israeli coast I show that the previously Atlanto-Mediterranean dominated biota of the Levant rocky reefs (intertidal and subtidal) on the Israeli shore is going through recent major shifts in its biodiversity. Several ecologically-important species (a reef-building vermetid gastropod, sea urchins and a large predatory snail) exhibited major population collapses while several key taxonomic groups (gastropods and bivalves and to some extent fish) are completely dominated by IndoPacific invaders. I suggest that this biogeographic shift may be partly driven by global climate change. The southeastern coastal waters of the Mediterranean have warmed by 2-3 degrees C in the past two decades and may have become too hot for some indigenous species and more hospitable to tropical species. This means that the climatic envelope of the native species may have shrunk or shifted. Recent lab and field experiments indicate that the abundant sea urchin, *Paracentrotus lividus*, is indeed dying during peak summer SST on the Israeli coast, and its feeding and reproductive potential are reduced by invasive herbivorous fish. Performance curves (e.g., photosynthesis) of several still-abundant (mainly during colder months) native species show that their physiological activity is greatly reduced when exposed to peak and future summer temperatures. Clearly, the ecological implications of these species collapses and invasions, including their effects on ecosystem functions, must be profound and are currently studied.

Keywords: Mediterranean, rocky reefs, bioinvasions, population collapses

Oral presentation

How will climate change affect our ability to meet Good Environmental Status for marine biodiversity?

Elliott M., Andersen J.H., Borja Á, Mazik K. and Painting S.

The EU Marine Strategy Framework Directive requires that Good Environmental Status (GEnS) should be achieved for European seas by 2020. GEnS will be based on 11 Descriptors which directly or indirectly reflect marine biodiversity and health; the Descriptors 1, 4 and 6 and their criteria and indicators specifically and respectively relate to biodiversity, food webs and seabed integrity within regional seas. EU Member States are thus charged with determining whether their seas deviate from GEnS, or a similar baseline, due to endogenic managed pressures (those resulting from activities within the sea area). However, superimposed on those changes are other changes due to exogenic unmanaged pressures such as climate change, thus making difficult the assessment of GEnS and the interrogation of causes and consequences of change. In particular, climate change is producing 'shifting baselines' which have to be accommodated in the monitoring and assessment of GEnS but also marine management has to accommodate 'unbounded boundaries' given the ecology of highly-mobile species and planktonic dispersal. This contribution presents conceptual models of the changes to the MSFD Descriptors as the result of climate change and then, where possible, quantifies those changes and links in the models across various time-scales. It presents a wide-ranging systematic review of the changes expected within the Descriptors based on field and laboratory studies from Europe and elsewhere and covering the macroalgae and macrophytes, benthic fauna, demersal and pelagic fish, plankton, birds and mammals. The analysis ranks the descriptors according to the likely or perceived degree of change and the difficulty of meeting GEnS against climate change. Here we not only consider current evidence but we are forward-looking by indicating possible future climate change issues. We further discuss the challenges for marine monitoring and management posed by having climate change superimposed on the effects of local activities. Consequently, this includes changes to the status which marine managers probably cannot control, for example the possible influx of alien species from opened Arctic sea-routes, the squeeze on habitats from relative sea-level rise, the migration of southern species into northern waters, the changes to reproductive cycles and spawning triggers due to changed temperature thresholds, the possible loss of resilience, and the impact of changes to nutrients in coastal waters as the result of land run-off variability due to North Atlantic Oscillation cycles. Hence we indicate the way that climate change may either exacerbate changes in the descriptors or, failing that, make it difficult to detect anthropogenic change because of the masking effect of climate change. It is considered that the messages within this contribution are applicable not only to European seas but also to other global areas, for example during the implementation of the US Oceans Act. These lessons are especially important given the focus of the implementation of the EU MSFD.

Keywords: MSFD, climate-change, descriptors, pressures, indicators, marine-management

Oral presentation

Holistic approach to analyze benthic fauna communities on the whole Baltic Sea

Gogina M. , Zettler M.L., Blomqvist M., Nygård H., Daunys D., Josefson A.B., Kotta J., Yermakov V., Warzocha J., Darr A. and Schiele K.

The data on the distribution of benthic macrofauna is collected together in one data-set to adequately cover the whole Baltic Sea basin. The data-set is comprising over thousand taxa at over 7 thousand locations (12 thousand visit events) sampled in years 2000-2013.

A number of works where previously published describing and mapping the benthic macrofauna communities in different sub-basins of the Baltic Sea. Nevertheless no synthesis or joint data analyses have being done for the entire Baltic Sea region. The focus of presented case study is the identification, description and mapping of benthic macrofauna communities, its habitats and functional features on the Baltic Sea wide scale, using holistic approach and conventional multivariate statistical methods together with and all available additional information. Sampling efforts from eight countries are aggregated, harmonized and analyzed to extract ecologically significant groups.

Species richness increase with salinity towards southwest and community composition changes. Therefore first characteristic (dominant) species are identified separately for each HELCOM sub-basin accounting for their frequency and relative abundance at location to extract the list of species feasible for the overall community analysis. Distinct benthic assemblages discriminated by particular species are defined, related to different spatial subarea and characterised by a certain variability of environmental parameters by means of various statistical methods (rank correlation, hierarchical clustering, indicator value, MDS, CCA, PLS). On this basis farther predictions using species distribution modeling methods are done in areas where gaps in sampling effort remain.

Study aims to set a baseline for future studies for better recognition of links between benthic fauna and ecosystem functioning.

Keywords: macrofauna assemblages, Baltic Sea, large scale

Oral presentation

Conceptual framework to assess the state of marine ecosystem services

Heiskanen A.-S., Kuosa H., Oinonen S., Saulamo K. and Uusitalo L.

Marine ecosystem services and goods are vital for the humans. Overexploitation of marine resources as well as increasing anthropogenic pressures (such as climate change, ocean acidification as well as pollution and habitat degradation) have damaged marine ecosystems and degraded their ability to provide services and benefits to human societies. In order to move towards sustainable management, we need to understand and model how the deterioration of ecosystem structures (biodiversity) and processes will impact flow of marine ecosystem services, and benefits for the human societies. Translating the ecosystem processes and functions as 'ecosystem services' helps to explain how society benefits from, and depends upon, ecosystems via the multiple services they provide. The current EU marine and maritime policies request ecosystem based assessment and management (e.g. EU Marine Strategy Framework Directive; MSFD), which calls for novel approaches to assess the status and trends of marine ecosystems and their capacity to provide marine ecosystem services. We present a approach towards a marine ecosystem service assessment following the Drivers-Pressures-State-Impact (on human Welfare)-Response (DPSWR) framework with the aim to link ecosystem services with the benefits from marine ecosystems and the economic drivers that influence the markets for the services and, at the same, cause pressures on the marine environment. We have compiled information on marine ecosystem structures and functions, and indicators for assessing the status of biodiversity and benthic integrity of marine ecosystems (sensu MSFD), as well as pressures impacting those, and use this information for the evaluation of the marine ecosystem capacity to provide services, and discuss the implications for marine policies and management.

Keywords: marine ecosystem services assessment, state, pressures

Oral presentation

Biodiversity indicator inventory – a catalogue software and a review of the current indicator set

Teixeira H., Berg T., Fürhaupter K., Uusitalo L., Heiskanen A.-S., Papadopoulou N., Bizsel K.C., Cochrane S, Churilova T. and Bizsel N.,

Within the DEVOTES project, a catalogue of existing indicators of marine biodiversity and closely related topics such as non-indigenous species, food webs, and seafloor integrity (EU Marine Strategy MSFD descriptors 1,2,4,6) has been established. Currently, the catalogue includes more than 500 entries with information on metadata ranging from indicator descriptions, data requirements, assignment to MSFD descriptors/criteria/indicators and developmental status to geographical coverage and applicable habitats, biodiversity components and related pressures. Both operational indicators and indicators in earlier stages of development are included.

The catalogue is available as a database with accompanying software, DEVOTool, which enables browsing the metadata as well as extracting lists of indicators using various criteria. Lists of indicators best fulfilling any set of criteria can be produced, enabling users to search e.g. for indicators that could be suitable to fill an identified gap in their marine area, such as missing biodiversity components or habitats. Additionally, an analysis tool is included that can produce simple rankings of specific subsets of indicators based on different criteria and calculations. The tool and the indicator catalogue will be continuously updated.

An analysis of the contents of this catalogue revealed that in the European Regional Seas, there are gaps mainly in indicators to address ecosystem structure, processes and functions, indicators for the genetic diversity, the effects of non-indigenous invasive species, and indicators related to the food web structure and functioning (productivity and size distribution). Furthermore, the analysis of the indicator set made it obvious that there is considerable overlap between the MSFD indicators of biodiversity, food webs, and seafloor integrity (D1, D4, D6). This may be due to different interpretation of the subordinate EU criteria by the EU Member States as well as double-counting of some indicators or biological processes. The definitions of these descriptors should therefore be clarified and potential overlap reduced. Ultimately, this catalogue of indicators has the potential to be used outside the range of the EU regional seas and of the scope of the EU Marine Strategy.

Keywords: Biodiversity, MSFD, indicator, food-webs, seafloor integrity, NIS

Oral presentation

Assessing the spatial patterns of marine benthic biodiversity using remote sensing and predictive modeling

Herkül K., Kotta J., Kutser T., Vahtmäe E.

Biodiversity is critical for maintaining and stabilizing ecosystem processes in changing environments. Decrease of biodiversity due to human activities has been observed in marine ecosystems. Understanding the spatial and temporal patterns of biodiversity is a prerequisite for studying the relationships between biodiversity and ecosystem functioning. Assessing the spatial distribution of biodiversity by the means of conventional field work methods is expensive and time-consuming and it yields biodiversity information only from the visited sites leaving most of the study area unsampled. Optical remote sensing can provide potential tools for producing spatially continuous biodiversity estimations over large spatial extents. Remotely sensed data and other georeferenced environmental data (e.g. bathymetry, wave exposure) can be used to predict biodiversity over areas that are sparsely sampled. The aims of this study are to 1) test the relationship between spectral variability of a high resolution hyperspectral airborne imagery and marine benthic biodiversity (spectral variation hypothesis, SVH), 2) use remotely sensed data and other georeferenced environmental data to predict the spatial patterns of biodiversity using mathematical modeling. The tested benthic biodiversity variables (species richness, Shannon index) showed statistically significant positive correlations with spectral heterogeneity. Thus, the relevance of SVH in marine benthic habitats was proved forming a prerequisite for the use of spectral variability in benthic biodiversity assessments. The products of the remotely sensed hyperspectral imagery were then used together with other environmental variables as an input for predicting the spatial distribution of biodiversity using mathematical modeling. Additionally to the modeling in the area covered with the hyperspectral imagery, a larger scale prediction of benthic biodiversity was made covering the whole Estonian sea area. The modeled distributions of biodiversity clearly improved the understanding of the spatial patterns of biodiversity by providing spatially continuous biodiversity estimates covering also the unsampled areas between field work sites. The results of this study demonstrated that combining field measurements, remote sensing, and mathematical modeling is the most rewarding approach to assess the spatial patterns of marine benthic biodiversity.

Keywords: benthic biodiversity, remote sensing, predictive modeling

Oral presentation

High through-put molecular methods in environmental monitoring: sample preparation and analytical pipelines

Lekang K., Hadziavdic K., Thompson E.M., Sandnes Skaar K. and Troedsson C.

Increasing anthropogenic activities in ocean areas add extra demands to monitor these environments to understand effects on the ecosystem. The biodiversity of marine sediments is highly relevant when monitoring changes in marine environments. Classical biomonitoring is however labor intensive and many monitoring programs are not well adapted to samples with high temporal and spatial resolution. A particularly interesting option is the use of molecular high through-put technology, such as next generation sequencing and phylogenetic microarrays. While these methods are able to obtain large amounts of information on the biodiversity, they are particularly sensitive to methodological errors in the initial steps of the pipeline, e.g. sample amounts, DNA extraction, PCR and purification. Here we have investigated the amount of sample material needed to cover the diversity of eukaryotic microorganisms in marine sediments in addition to testing genomic DNA extraction and purification methods as well as the development of a robust pipeline for exploring the diversity of eukaryotic microorganisms in marine sediments. Using this pipeline we conducted 454-pyrosequencing of eukaryotic microorganisms in marine sediments surrounding petroleum platforms in the North Sea. Our data indicate that we can separate samples based on 18S rRNA sequencing data similar to classical monitoring methods. We have further designed a phylogenetic microarray targeting specific 18S rRNA fragments present in these sediments. The microarray has been validated under controlled conditions and tested on marine sediments. Our data indicate that we can obtain biodiversity separations between sediments, reflecting that which has been observed using classical methods, but with a high level of complexity and resolution.

Keywords: biomonitoring, 18S rRNA, 454-pyrosequencing, Microarray

Oral presentation

Ecosystem effects of exploitation

Lotze H.K., Britten G. and Schmidt A.

Humans have a long history of exploiting marine resources and continue to do so today, although the main target species have shifted over time. While historically marine mammals, sea turtles, and birds were in high demand, exploitation in the 20th century has increasingly focused on fish, and recently shifted to marine invertebrates and plants in some regions. In this presentation, we will address the ecosystem consequences of these different types of exploitation in the past and today. We will present cases studies using different approaches to analyze the effects of exploitation on ecosystem structure, functioning and the services they provide for human well-being. First, combining a synthesis of historical changes and a food-web modeling approach we evaluate the long-term, human-induced changes in marine resource species of the Adriatic Sea in the Mediterranean and how this has affected marine diversity, food-web structure, ecosystem functioning and the robustness of the system to further species loss. Second, using a community matrix approach we analyze changes in the stability of a coastal fish community in the Mediterranean in the course of overfishing based on three stability indices: resilience, resistance and reactivity. Third, performing large-scale field surveys in Atlantic Canada and a global meta-analysis we determine the ecosystem services provided by coastal vegetated habitats, such as macroalgal canopies, and how these have been altered by exploitation and other human impacts. These case studies will serve as a basis for discussing the effects of exploitation on the structure, functioning and services of marine ecosystems, and how this knowledge can be used for better management and conservation.

Keywords: diversity, food-web structure, stability, ecosystem-services, human-impacts

Oral presentation

Spatial overlap of key conservation areas for marine predators and human pressures in southern European waters management strategies

Louzao M., Vázquez J.A., Murcia J.L., Valeiras X., García Barcelona S., Pierce G.J., González Quirós R., M. and Santos B.

The European Union has adopted the Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC) with the objective of achieving or maintaining Good Environmental Status (GES) of European waters by 2020. The MSFD constitutes the legislative instrument devised to protect the marine environment across European waters from the human-related environmental changes that had already negatively affected marine ecosystem functioning and the dynamics of many populations of marine organisms. To achieve GES, Member States will need to address all human activities that have an impact on the marine environment, through an integrated ecosystem-based approach that is spatially explicit. Multidisciplinary surveys are an ideal platform that can provide a synoptic view of the status of marine habitats. PELACUS surveys are conducted annually for acoustic assessment and mapping of the oceanographic and biological conditions of the northern and northwestern shelf of the Iberian Peninsula. The main objective is to monitor the pelagic ecosystem collecting concurrent information on several trophic levels. Since 2007, marine mammal and seabirds sightings have been recorded by dedicated observers, who also collect information on the type and abundance of different types of human pressures (e.g. fishing, marine debris). Using distance sampling methodology, we were able to estimate relative abundance of marine predator species in the region in addition to mapping the areas where they could be more at risk from anthropogenic pressures such as fishing and marine litter. Our objective is to highlight the importance of observer programmes not only in providing (1) baseline information on distribution and abundance of top predators, but (2) also additional information on human pressures. Both types of data are needed to inform any conservation and management plans such as the MSFD.

Keywords: Multidisciplinary surveys, marine predators, human pressures

Oral presentation

The European Marine Strategy Framework Directive: barriers to its implementation

Luisetti T., Boyes S, Elliott M., Börger T., Atkins J.P., Oinonen S.M., Papadopoulou N., Danovaro R., Uyarra M.C., Paltriguera L., Bizsel K.C., Burdon D., Carugati L., Eronat H., Heiskanen A.-S., Kaboglu G., Murillas A., Petani B., Pusceddu A., Salojärvi J., Smith C.J., Tekis E., Vassilopoulou V., and Austen M.C.

In the frame of the Marine Strategy Framework Directive (MSFD) implementation, in 2012 EU member states (MS) provided an initial assessment (IA) of the environmental status of their marine waters, determined Good Environmental Status (GEnS), and established targets and indicators to achieve or maintain GEnS. Several documented legislative and socio-economic barriers have been encountered by MS in this first phase: weaknesses in the MSFD text and effectiveness of the Regional Seas Conventions at coordinating and ensuring coherence in the regional implementation of the MSFD; knowledge barriers, especially a lack of biophysical and socio-economic data allowing only a limited application of an ecosystem approach and of an ecosystem services framework to the valuation of the marine environment and assessment of the costs of degradation; and economic barriers, especially constrained funding available to MS to overcome knowledge barriers and achieve the objectives of the MSFD. We investigate here whether these barriers are likely to be overcome by all MS in the given timeframe or in the future. As evidence, we highlight the legislative, administrative, knowledge and socio-economic barriers encountered by selected MS (Finland, Greece, Italy, Spain, and the UK) in their implementation of the first phase of MSFD. We also examine the experience of an initial assessment as described in Article 8.1 of the Directive for a potential candidate MS (Turkey). While delay in implementation is likely, at least in some MS, we explore possible ways forward to overcome the present barriers to the implementation of MSFD and hence achievement of GEnS.

Keywords: MSF; assessment; barrier; GEnS; ecosystem services

Oral presentation

Looking for measure of the status of marine biodiversity along the gradient of cumulative human pressure, case study from northern Gulf of Riga, the Baltic Sea.

Martin G., Torn K., Püss T., Rostin I. and Martin K.

Influence of different human activities on near coastal marine biodiversity is generally well established. Effect of different single types of human activities on different components of marine and coastal biodiversity is often well catalogued and this knowledge is often used for assessing the possible impacts of different new developments on marine environment. While dealing with single pressures and single biodiversity components is usually not a problem the estimating of cumulative impacts on the whole ecosystem is much more challenging. Different legal instruments as e.g. EU Marine Strategy Framework Directive require assessment of different components of marine environment on the basis of well-established indicators and assessment schemes. Quality standard for these indicators are quite high and so there is a lack in well documented and operational indicators applicable on larger geographical scales. In the framework of EU LIFE+ project MARMONI “Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea” set of innovative, cost effective marine biodiversity indicators has been developed and tested to be included in the national marine biodiversity assessment schemes. Among the set there are two indicators reflecting near coastal benthic biodiversity – Stormcast Index and Substrate Colonization Index. These two developed measures of benthic biodiversity were developed and tested against the both natural and human induced pressure gradients in the northern part of the Gulf of Riga. It was proved that both indexes reflect structure of surrounding biological environment and responded to the complex of human induced pressures ruled by eutrophication. In the process of the development For both developed indexes reference conditions were established using modelling of different scenarios of eutrophication situation.

Keywords: Benthic biodiversity, Tha Baltic Sea

Oral presentation

Exploring links from eutrophication to biodiversity: two descriptors accessing the good environmental status of the European seas

Jayasinghe R.P.P.K. and Newton A.

Marine environments and ecosystems provide valuable goods and services to humans including food, transport and recreational activities. However, marine ecosystems are being threatened by eutrophication caused mainly by human activities such as agriculture, urbanization, industrialization and aquaculture. Pressures from unbalanced nutrient inputs to aquatic ecosystems accelerate phytoplankton growth, and sometimes leading to harmful algal blooms (HABs) and or hypoxic events. In many coastal and marine environments nowadays, such as the Baltic Sea and the Black Sea are facing this problem. The European Marine Strategy Framework Directive (MSFD, 2008/56/EC), has 11 Descriptors to assess good environmental status (GES). In year 2020 the objectives to be reached using the ecosystem approach to management of marine environment. Biodiversity is descriptor 1 and Eutrophication is descriptor 5, however, eutrophication may alter the biodiversity status of the marine environment. Therefore, the present study was carried out to explore the links between eutrophication and biodiversity descriptors for GES. Using a DPSIR framework the Drivers and Pressures for eutrophication were identified and followed through to show ecological state changes. The study revealed that various groups/taxa of biota such as phytoplankton, zooplankton, zoobenthos, fish, marine birds, reptiles and marine are being affected by eutrophication. Likewise, sea grass communities were also affected. Examples were found from all European seas, so a conceptual model was developed to illustrate how eutrophication affects the state of the biodiversity in marine ecosystems. The conceptual model explores the relationships between two descriptors in marine food webs, another GES descriptor. In conclusion, the links between the descriptors of GES should be explored to show the significant interactions between them. These may be useful to simplify assessments, but may also lead to bias in the assessment through double counting. It is therefore important to consider these links, when evaluating the environmental status of the regional seas.

Keywords: MSFD, eutrophication, biodiversity, GES, descriptors

Oral presentation

Monitoring Networks Currently Used in European Seas: Is The Marine Monitoring for the Marine Strategy Framework Directive Fit-For-Purpose?

Patrício J., Little S., Mazik K., Zampoukas N., Teixeira H., Uyarra M.C., Solaun O., Papadopoulou N., Zenetos A., Kaboglu G., Churilova T., Kryvenko O., Moncheva S., Stefanova K., Bucas M., Elliott M.

By 2020 EU Member States are obliged to demonstrate achievement of GEnS (Good Environmental Status) for their marine waters. Through the Regional Seas Conventions, each Member State is required to develop marine strategy for their waters, in coordination with other countries within the same marine region or subregion. Coherent monitoring forms a key component of this strategy. An in-depth analysis of marine monitoring networks in Europe, carried out under the DEVOTES FP7 project, aimed at assessing the status of marine biodiversity monitoring, has focused on the Marine Strategy Framework Descriptors 1 (biological diversity), 2 (non-indigenous species), 4 (food-webs) and 6 (seafloor integrity). This provides an initial assessment of the potential for the effective implementation of the MSFD and the potential for effective assessment of GEnS. Our analysis includes over 210 monitoring programmes reported by ten EU Member States (Bulgaria, Denmark, UK, France, Germany, Greece, Italy, Lithuania, Portugal and Spain) and three countries that share European Regional Seas boundaries (Norway, Turkey and Ukraine). This has allowed us 1) to critically evaluate the monitoring activities in Europe (i.e. what monitoring is being currently performed, why it is being performed, which biodiversity descriptors, biological components and habitats are addressed and to what pressures it is linked); 2) to identify gaps in monitoring based in the information compiled; 3) to identify needs for further development for marine biodiversity monitoring to improve and optimize the monitoring for implementing and fulfilling the MSFD and 4) to promote or foster harmonization among countries sharing marine regions for joint GEnS assessments. Here we give an overview of the Catalogue of Monitoring Networks, details at the European, regional and subregional sea level of each monitoring activity, as well as the four descriptors, 11 biodiversity components, 22 habitats (18 seabed and 5 water column) and the 37 pressures addressed (both local manageable and widespread unmanageable). The monitoring network analysis shows gaps related to pressures at Regional Sea and subregional level. A SWOT analysis (strengths, weaknesses, opportunities and threats) of the existing monitoring networks across Europe show that there is a good basis on which to build although several countries and regions will not be able to comprehensively judge the status of their areas unless the monitoring is increased in intensity and coverage both of areas and components. Given that some countries aim to base their MSFD monitoring only on existing programmes then there is a concern that the programmes may not be fit for purpose. Hence, our results are especially relevant to the development of comprehensive and coordinated monitoring networks throughout Europe, for policy makers, government agencies and the regulatory bodies responsible for implementing the MSFD.

Keywords: Monitoring, MSFD, biodiversity descriptors, SWOT analysis, Regional Seas

Oral presentation

Linking biodiversity indicators, ecosystem functioning, provision of services and human well-being in estuarine systems: Application of a conceptual framework

Pinto R., de Jonge V.N., Marques J.C.

Assuming that human well-being strongly relies on the services provided by well-functioning ecosystems, changes in the ecological functioning of any system can have direct and indirect effects on human welfare. Intensive land use and tourism have expanded in recent decades along coastal ecosystems, together with increasing demands for water, food and energy; all of these factors intensify the exploitation of natural resources. Many of the interrelations between ecosystem functioning and the provision of ecosystem services (ES) still require quantification in estuarine systems. A conceptual framework to assess such links in a spatially and temporally explicit manner is proposed and applied to the Mondego Estuary (Portugal). This framework relies on three consecutive steps and discriminates among biodiversity structural components, ecosystem functioning and stability and the services provided by the ecosystem. Disturbances in abiotic factors were found to have a direct effect on biodiversity, ecosystem functioning and the provision of ES. The observed changes in the species composition of communities had a positive effect on the ecosystem's productivity and stability. Moreover, the observed changes in the estuarine ES provision are likely to arise from changing structural and abiotic factors and in the present case from the loss or decline of locally abundant species. This study also indicates that linear relationships between biodiversity, ecosystem functioning and services provision are unlikely to occur in estuarine systems. Instead, cumulative and complex relations are observed between factors on both temporal and spatial scales. In this context, the results suggest several additional conclusions: (1) biodiversity and ecosystem functioning interaction with human well-being need to be incorporated into decision-making processes aimed at the conservative management of systems; (2) the institutional use of research results must be part of the design and implementation of sustainable management activities; and (3) more integrative tools/studies are required to account for the interactions of estuarine ecosystems with surrounding socio-economic activities. Therefore, when performing integrated assessments of ecosystem dynamics, it becomes essential to consider not only the effects of biodiversity and ecosystem functioning on services provision but also the effects that human well-being and ES provision may have on estuarine biodiversity and ecosystem functioning. The proposed framework implies taking into account both the functional and the commodities points of view upon natural ecosystems and by this representing a line of thought which will deserve further research to explore more in detail the conceptual links between biodiversity–ecosystem functioning–services provided.

Keywords: Ecosystem approach; BEF; Ecosystem services; Estuaries

Oral presentation

Ecological Geography of the Mediterranean Sea

Reygondeau G., Albouy C., Hattab T., Benedetti F., Irisson J.O., Gasparini S., Guieu C., Ayata S. and Koubbi P.

In recent decades, it has been found useful to partition the pelagic environment using the concept of ecoregionalisation within each partition it is assumed that environmental conditions and species associations are distinguishable and unique. Indeed, each partition of the ocean that has been proposed aimed to delineate the main oceanographical, ecological patterns and discontinuities to provide a geographical framework of marine ecosystems for ecological studies and management purposes. The aim of the present work (MERMEX/PERSEUS projects) is to integrate and process existing data on the environmental condition and biological observations (from phytoplankton to top predators) in order to define and characterize the Mediterranean' ecosystems.

A comprehensive database informed on environmental conditions (22 parameters), biological observations (more than 1500 species from plankton to whales) and human pressure (Halpern et al., 2008) is gathered from online database, cruise and published article. These various dataset allow the multidisciplinary view required to understand the interactions between climate, marine species and anthropogenic activity in the Mediterranean marine ecosystems. Then, based on multi clustering methodology and on environmental niche modeling, a two level partition of the Mediterranean Sea is proposed: biogeochemical regions (biotopes) and the ecoregions (associated biocenoses).

Results from this study allow us to identify the main ecological division of the basin on the basis of environmental features and biodiversity patterns (from phytoplankton to whales). Relations from environment to high trophic species are investigated (biodiversity, size of the organism among the environmental gradient) at each trophic level. Finally, based on the ecological framework obtained, the main anthropogenic pressures are characterized.

Keywords: ecoregions, Mediterranean Sea, E2E, ecological niche

Oral presentation

Developing indicators to meet European policy requirements: How to assess the health of benthic habitats?

Robson L.

To determine the health of our marine environment, indicator driven assessments can be used to inform reporting requirements under multiple policy instruments. At the European level, these policy instruments include the Marine Strategy Framework Directive (MSFD), the Habitats Directive and the Regional Sea Conventions.

A key requirement of the MSFD is that Member States work together on its delivery in a coherent and coordinated way, to ensure coherence in assessments across Europe. The UK is working through the OSPAR Convention, via the ICG-COBAM (Intersessional Correspondence Group on Biodiversity Assessment and Monitoring), to coordinate and develop a set of common indicators to measure Good Environmental Status for marine biodiversity across the North East Atlantic. In support of this process the UK is progressing research to define indicators for a number of benthic habitats.

In the UK good progress has been made for those benthic habitats which are well understood, where active research is ongoing and where data are readily available (e.g. *Modiolus modiolus* beds). However, for many benthic habitats significant knowledge and data gaps remain which can hinder the development of operational indicators. For example, information is often lacking on the ecological diversity of benthic habitats, the environmental factors that can influence benthic habitat distribution, and an understanding of how benthic habitats are affected by human pressures. Lack of survey data on habitats, environmental variables and pressures means statistical validation of indicators is further hindered. These information gaps therefore restrict our ability to link habitat change with natural variation and/or anthropogenic-induced variation and thus to make the indicators fully operational.

A case study is presented here to demonstrate how indicators are being developed for shallow circalittoral rock communities which are dominated by sponges and anthozoans. Although these benthic habitat communities are well described there is a need to: identify which type of metrics can be measured from existing data; identify what the important and representative species or species groups are; statistically analyse existing data to explore the spatial and temporal variability of the identified indicator metrics; investigate how variation can be explained by the associated environmental variables (e.g. depth / salinity etc and any relevant / important human pressures); and understand how much of the variability can be attributed to environmental parameters and how much can be attributed to the pressure(s) of interest. Initial results will be presented and discussed as case study for developing indicators for information-poor benthic habitats.

Finally, it is apparent that to deliver coherent and coordinated assessments across Europe there is a need for Member States to work together. In particular there is a need to exchange knowledge and share data to support the coordination and development of proposed common indicators and to make them operational.

Keywords: MSFD, indicators, benthic habitats, status assessment
Oral presentation

Biodiversity in the plankton: are ecosystem services influenced by evolutionary mechanisms?

Rynearson T.A. and Whittaker K.A.

Primary production by phytoplankton generates the organic carbon that fuels marine food webs. Predictions of phytoplankton responses to climate change are often based on experiments conducted in the laboratory on single clones. In contrast, there is very little understanding of how much clonal diversity exists in the field and how that diversity is structured over space and time. To fill these knowledge gaps, we used DNA fingerprinting techniques to determine the genetic diversity of the diatom *Thalassiosira rotula* in field samples collected from around the globe. This cosmopolitan diatom species is found in coastal regions, including those impacted by human activity, where it can form large blooms. Analysis of over 400 single cell isolates collected from 8 locations in the northern and southern hemispheres at 6 microsatellite loci revealed high levels of clonal diversity: of 449 cells, 447 were genetically different. We also identified five genetically different populations with unique patterns of occurrence over space and time. The geographic patterns suggest that both dispersal and environmental conditions play important roles in structuring diversity in this phytoplankton species. Because *T. rotula* contains high levels of diversity on which natural selection can act, it is likely that this important primary producer will be resilient to many of the predicted environmental impacts of climate change, including changes in water temperatures and nutrient supply. Marine biodiversity assessments are most often focused on diversity among species. These results highlight the importance of assessing diversity within species as a way to better understand and ultimately predict the responses of marine biota to climate change.

Keywords: phytoplankton, diatoms, DNA fingerprinting, genetic connectivity

Oral presentation

The role of biodiversity in marine ecosystem functioning and their relevance to the implementation of the Marine Strategy Framework Directive, its monitoring, modelling and management

Strong J.A., Mazik K., Elliott M., Franco A., Queiros A., Somerfield P., Widdicombe S., Smith C., Papadopoulou N., Bizsel K.C., Garces E., Moncheva S. and Stefanova K.

The “biodiversity ecosystem functioning relationship” (BEF) refers to the way in which biodiversity, a structural feature, influences ecosystem functioning, itself defined as a combination of processes. In essence, this may indicate that a highly diverse system is required in order to allow ecological functioning to be maintained. The BEF debate is well-developed in terrestrial and freshwater systems but it has only recently been considered in coastal and marine systems. As marine and transitional waters include ecosystems with both naturally low (transitional waters) and high (marine waters) diversity then it is important to consider the relationships between diversity, functioning and hence resilience and resistance to human and natural stressors. Currently we have an incomplete understanding of the i) diversity-ecosystem functioning link across various levels of biological organization, ii) diversity interactions across different food-webs, and iii) mechanisms that modify the functioning at similar levels of biodiversity (functional role of species). Hence, we lack a model of diversity-functioning relationship which can be applied widely for monitoring systems and in understanding its repercussions in the pressure-impact chain.

The objective of this review was to rigorously appraise experimental/manipulative findings from marine BEF studies and will look for evidence to indicate whether similar or different relationships are consistent across different community components and levels of biological organisation. It is concluded that by analyzing functioning at various levels of biological organization (from the cell to the ecosystem), for example using individual attributes, population characteristics and the functional guild approach for communities, in which the features of the taxa rather than their mere identities are considered, then functioning can be analyzed. This may indicate similarities irrespective of geographic location. The review then explores the role of this approach in defining indicators, carrying out monitoring and determining marine health in general and specifically Good Environmental Status under the Marine Strategy Framework Directive.

Keywords: Biodiversity Ecosystem Functioning Marine Review

Oral presentation

Tool for assessing status of marine and coastal biodiversity on the example of Gulf of Riga, NE Baltic Sea.

Martin G., Torn K., and Martin K.

Tool for assessment of the status of marine and coastal biodiversity was developed in the framework of LIFE+ MARMONI (Innovative approaches for marine biodiversity monitoring and assessment of conservation status of nature values in the Baltic Sea) project. Assessment of the status of marine and coastal biodiversity is required by EU Marine Strategy Framework Directive. At the same time, no methodologically sound and straightforward assessment scheme exists so far for the Baltic Sea area. Our approach was to develop the assessment scheme and practical tool following several general principles: 1) assessment scheme is based on set of biodiversity indicators covering different features and components of marine and coastal biodiversity; 2) assessment is done in one common software package enabling assessment results on indicator, biodiversity component and whole waterbody level; 3) assessment result is fully comparable and follows requirements of EU MSFD could be used in national reporting process; 4) assessment result shows both actual status of biodiversity and level of pressures altering different components of marine and coastal biodiversity in the assessment area. Tool was tested in the Gulf of Riga project area, totally over 30 different indicators were used covering different aspects of marine and coastal biodiversity. Main methodological aspects and conditions of applicability of the Tool are presented and discussed. Possible directions for further development of similar tools are presented.

Keywords: Biodiversity, assessment tool

Oral presentation

Session D2: Communities of practice for supporting long-term sustainability of the world's oceans

Oral Presentations

Tuesday 24 June 2014, 11:00-12:30 Parallel session 1

Topic: Communities of practice and processes shaping ocean governance

Chair: Isabel Torres de Noronha

Room D3

Time	Presenter	Title
11:00-11:15	Roura, Ricardo	Environmental NGOs and ocean governance: Linking the public and decision makers in Antarctica's Southern Ocean
11:15-11:30	Gonçalves, Leandra	The collective construction of a law of the sea in Brazil
11:30-11:45	Gorris, Philipp	Organizing regional marine governance: A structural analysis of case studies in Brazil and Indonesia
11:45-12:00	Gonçalves, Leandra	Engaging Brazilian knowledge networks in the Future Ocean Alliance
12:00-12:15	Gonçalves, Leandra	The role of epistemic communities in the global governance of the oceans
12:15-12:30	All	Discussion

Tuesday 24 June 2014, 14:00-15:30 Parallel session 2

Topic: Communities of practice promoting best available knowledge in addressing global change

Chairs: Oran R. Young and Cyndy Chandler

Room D3

Time	Presenter	Title
14:00-14:15	Fox, Peter	Facilitating Next Generation Science Collaboration: Marine Ecosystems Status Reports and Assessments
14:15-14:30	Koslow, Tony	A model for global cooperative ocean observation networks as the basis for ecosystem-based management, ocean climate research and assessment of ecosystem change
14:30-14:45	Streftaris, Nikos	First steps towards Suggesting and Supporting Policies to Achieve Good Environmental Status in the Mediterranean and the Black Sea - PERSEUS Project
14:45-15:00	Torres de Noronha, Isabel	The EU Integrated Maritime Policy: Challenges and Opportunities for Sharing Ocean Knowledge and Engaging its Communities towards the Sustainable Management of the Ocean in a Setting of Multilevel Governance
15:00-15:30	All	Discussion

Session D2: Communities of practice

Tuesday 24 June 2014, 16:00-17:30 Parallel session 3

Topic: The Way Forward: Adding Value to Knowledge and Communities of Practice through Ocean Governance in a Setting of Global Change

Chairs: Peter Fox & Oran R. Young

Room D3

Time	Presenter	Title
16:00-16:15	Glaser, Marion	Netmapping of Global Ocean Governance: Reporting on the Results of W4
16:15-16:20	Young, Oran	The Future of the Ocean: Knowledge and Action
16:20-16:25	Mahon, Robin	The open ocean: Is there an emerging structure among ocean governance arrangements ?
16:25-16:35	Torres de Noronha, Isabel	Why do We Need the Future Ocean Alliance? Defragging the Global Ocean in the Context of Ecosystem Based Management
16:35-17:15	All	Open Debate on integration & Final Conclusions

Poster Presentations

Tuesday 24 June 2014, 17:30, Poster Session 1

ID	Presenter	Title
D2.P1	Mejia, Sandra	Supporting local economic initiatives in fishing communities to contribute a responsible stewardship and management of sustainable seafood (Nicaragua case in Golfo de Fonseca)
D2.P2	Roura, Ricardo	Strategic thinking for marine conservation in Antarctica: A case study of the establishment of Marine Protected Areas in the Southern Ocean

Session D2 Communities of practice – Abstracts

Facilitating next generation science collaboration: Marine ecosystems status reports and assessments

Fox P. and the ECOOP team

A 3-year initiative has developed and deployed an online environment for the development of marine fisheries ecosystem status report retaining traceability and verifiability of developed indicators in figures, tables and supporting captions and narratives. This environment is intended to be a key step toward science collaborations for an integrated ecosystem assessment (IEA) system based on information science and semantic technologies. The intention is to advance the capacity of an IEA to provide the foundation for synthesis and quantitative analysis of natural and socio-economic ecosystem information to support ecosystem-based management. In particular, the initiative is create the capacity to assess the impacts of changing climate on two large marine ecosystems: the northeast U.S. and the California Current. Enhanced collaboration is required to achieve these goals: interaction and information sharing within and among diverse data providers, analysis tool developers and user groups that constitute the broader coastal and marine ecosystem science application community. This presentation indicates the methods and technical approaches used and how semantic solutions are fundamental to this initiative. We conclude with future prospects for application to marine ecosystem studies worldwide.

Keywords: marine fisheries; ecosystem status; science collaboration

Oral presentation

Netmapping of Global Ocean Governance: Reporting on the results of W4

Glaser M. Holzkämper E. and Gorris P.

On Day 1 of the conference (Monday) a workshop (W4) on understanding global ocean governance will engage in a collective thinking exercise (netmapping in world-café style) to identify the strengths and weaknesses of current global ocean governance in addressing key issues for ocean sustainability. The results from this collective multi-stage exercise will be presented. Further avenues towards generating and sharing knowledge on global ocean governance and associated social networks will be discussed.

Keywords: governance, netmapping, network

Oral presentation

The collective construction of a law of the sea in Brazil

Gonçalves L. and Hirota M.

This paper aims to describe the process of participatory development of a law of the sea as a tool aimed at promoting greater governance for the Brazilian marine and coastal zones through the involvement of experts from various sectors of the society and based on scientific information. It is also an opportunity to discuss what are the challenges and opportunities that may arise in the future with the possible approval and subsequent implementation of the law of the sea in regards to the collective participation and involvement of various sectors. Despite the Brazilian coastal and marine zone environmental, economic, and social importance, this heritage is threatened due to interrelated problems such as limited government and political support for the implementation of the existing instruments; absence of innovative and convergent instruments of public policy, and the strong increase of the non-regulated production sector. Through interviews, technical meetings, and scientific data compilations, Fundação SOS Mata Atlântica facilitated the participatory and democratic development of a proposal of a new instrument of public policy – the national Law of the Sea. This process sought to evaluate the possible effects that this new instrument could introduce into the improvement of coastal and marine governance in Brazil. The bill was introduced in Congress in late 2013 and follows the regular procedures and thematic committees for approval and presidential enactment - a process that could take many years. It was sought to ensure this process with the involvement of the sectors of artisanal fishing, industrial fishing, productive sector, government agencies, educational and research institutions, and civil society organizations aimed at ensuring representation and participation of the various sectors in monitoring the long process of proper conduct, improvement, and maintenance of the basic principles for which the law needs to be formulated. The collective development performed so far ensured that the law was not only based on principles of environmental conservation, but also brought elements and innovative tools such as marine spatial planning that considers the natural attributes of the regions and seeks to reconcile the various uses of the sea. In addition, the bill provides instruments that encourage the use of non-extractive activities, such as tourism, through grants, which so far are mainly provided by the Brazilian government for extractive activities such as oil exploration and industrial fishing. It was also sought to include principles such as polluter-payer and user-payer, internalizing environmental costs in the production process, so the polluter must bear the cost of remediation actions and the user of natural resources must pay to use them. The development of this instrument for modern and innovative public policy represents a major breakthrough for the actions of marine conservation in Brazil in order to strengthen the on-going initiatives. This research is a contribution to knowledge and provides an opportunity to discuss and evaluate the contribution of this bill in the improvement of coastal and marine governance in the country.

Keywords: law of the sea, oceans governance

Oral presentation

Engaging Brazilian knowledge networks in the Future Ocean Alliance

Cavaleri Gerhardinger L., Prates A.P., Seixas C.S., Mesquita B., Padovani B., Vila Nova D., Herbst D., Grecco de Carvalho F., Torres de Noronha I., Merico L.F., Gonçalves L., Polette M., Glaser M., Fox P., Gorris P. and Scharer R.

The vision of the Future Ocean Alliance™ (FOA™) is to build one single ocean community connected at all levels, across scales, and disciplines with the support of informatics to enhance knowledge and ocean governance processes. To implement FOA's vision in Brazil, it is necessary to consider the implications of engaging the country's coastal-marine networks. How can FOA's mission, objectives, priority actions and expected results add value and generate synergies to existing operating coastal-marine networks? This paper will systematically explore these questions as informed by the progressive creation of a network that implements the FOA vision and mission toward the development of a FOA chapter in Brazil (FOA-BR). As this process evolves, we will describe the steps adopted in Brazil during the inception and emergence of this cross-institutional process focusing on an updated mapping of the relevant organizations types, existing knowledge sharing networks, on-going governance processes and issues. Although numerous innovative coastal-marine initiatives and networks exist, information is still largely fragmented and often disconnected from policy problem-solving arenas. Thus a FOA-like functional role is seemingly lacking in Brazil and therefore an opportunity exists to empower individuals and institutions into effective coalitions - a role that FOA as an intended bridging organisation will be able to provide. While our mapping and strategy will be inclusive of existing Brazilian networks, we will offer a practical example to illustrate how FOA in Brazil may evolve in order to achieve FOA's vision and mission. Firstly, it is worth noting that in Brazil, FOA's knowledge network approach needs to focus on relevant semantic webs spanning transversally across people and institutions at multiple levels. Secondly, the implementation of FOA's vision in Brazil needs to embody meaningful criteria, principles and deliberative structures to prioritize where to place its efforts. Since both of these needs resonate with the 'Ombudsperson of the Sea' (Ouvidoria do Mar - ouvidoriadomar.tumblr.com), this paper will explore the potential interactions of this initiative with FOA. The Ombudsperson of the Sea was a self-organized event during the People's Summit (Rio de Janeiro, 18 June 2012), with the objective of creating opportunities for civil society to 'understand the crisis and formulate proactive and integrated agendas amongst coastal-marine networks'. The initiation event gathered over a hundred people from more than 70 organizations to produce a Programmatic Agenda for Coastal-Marine Networks. It was used an interactive methodology to define twenty-five Convergence Codes (CCs) that allow a clear visualization of priority links for synergy amongst coastal-marine networks. Each CC offers a sufficiently broad pathway to enable future detailing; and is specific enough to allow mutual acknowledgment of the most relevant semantic linkages amongst networks. The CCs already offer a legitimate priority-map where FOA-BR may kick-off the structuring of a knowledge network, i.e. with the support of informatics and information technologies. Our paper will describe this in further detail and explore needed mechanisms/structures to arrive at solutions for achieving the CCs in the Brazil FOA context.

Keywords: Future Ocean Alliance, Collective
Oral presentation

The role of epistemic communities in the global governance of the oceans

Gonçalves L.

This paper seeks to identify and describe who are the epistemic community acting on the international cooperation promoted under Regional Fisheries Management Organisations (RFMOs) and discuss their influence at international policies. Epistemic community is defined here as a network of professionals with recognised knowledge and skill in a particular issue-area. Members of an epistemic community also share causal beliefs, which result from their analysis of practices that contribute to set of problems in their issue-area that then allow them to see the multiple links between policy and outcomes and identifying salient points for negotiation with States. To evaluate the epistemic community influence, it was chosen three RFMOs, which are, as defined by FAO as “intergovernmental fisheries organisations or arrangements, as appropriate, that have the competence to establish fisheries conservation and management measures”. The organisations are open both to countries in the region (“coastal states”) and countries with interests in the fisheries concerned. While some RFMOs have a purely advisory role, most have management powers to set catch and fishing effort limits, technical measures, and control obligations. Almost all of the global high seas are now covered by at least one RFMO, but their effectiveness in conserving the fishery stocks therein has been questioned lately, as many stocks have declined. Experts are highlighting that global fisheries are in crisis. The UN Food and Agriculture Organization (FAO) estimate that about 87% of global fisheries are either fully exploited or overexploited. Increasing technological effort and a global expansion of fisheries are failing to further increase catches. For this analysis, public documents of the meetings of the three RFMOs – ICCAT, CCAMLR, CCSBT are being evaluated to identify the epistemic communities and how they are acting to promote a change on fisheries management based on their usable knowledge. The existence and impact of epistemic communities and their ideas depend largely on the nature and the political context. However, the partial results already observed in this study with respect to this specific RFMOs shows that there is a consensus between the epistemic community regarding the need to address fishery collapse, but, this appeal has not been influential enough to change or re-direct the position of powerful countries, whose remain resistant to any change in the global governance of the oceans. It is evident from the results that the priority of RFMOs – or at least of their member countries – has been first and foremost to guide the exploitation of fish stocks aiming economics benefits. While conservation is part of nearly all of their mandates, they have yet to demonstrate a genuine commitment to it on the water. This study represents a great opportunity to discuss how epistemic communities are acting on RFMOs, and how they can influence powerful states to listen to truth to contribute with the fishery stock recovery and global governance of the oceans.

Keywords: epistemic communities; RFMOs; oceans governance

Oral presentation

Organizing regional marine governance: A structural analysis of case studies in Brazil and Indonesia

Gorris P. and Glaser M.

Indonesia and Brazil are large countries with long coastlines and highly diverse marine ecosystems. In both countries, increasing competition over scarce resources and deteriorating quality of marine ecosystems due to increasing human population and intensification of marine resource use has led to growing environmental concerns. In order to address these, the two countries have adopted different marine governance strategies. We understand marine governance as a continuous and dynamic social process, involving government and non-government stakeholders, that regulates human-nature interaction in marine social-ecological systems. These social processes can be represented as interaction patterns of collaboration and cooperation that constitute different governance systems. The particular challenge of environmental governance is that it requires rapid responses in context of complexity, diversity and unpredictable multi-scale dynamics, and at same time it needs to be robust. The organizational problem is to integrate multiple stakeholders into a robust network that is capable of continuously generating appropriate social-ecological knowledge and of facilitating its accumulation at certain interfaces and decision making bodies. This provides for the incorporation of social-ecological feed-backs into environmental governance systems to arrive at timely and informed management decisions. Over the past decade, integrating larger marine territories into spatial planning and management has been strongly promoted to strengthen conservation efforts at ecologically relevant scales. Approaching marine management at larger scales poses new organizational challenges and studies of marine governance regions at the subnational level are needed.

This study sheds light on how the regional marine governance systems are organized in two case study areas in Brazil and Indonesia and examines possibilities and constraints for robust and adaptive governance. Social interaction patterns surrounding the use and management of coral reef ecosystems are analyzed from a regional perspective using social network analysis (SNA) and qualitative methods. SNA considers the attributes of actors whilst focusing on the relations among actors, how relations are structured into an overall network and how actors are positioned within networks. Using a stakeholder roster, face-to-face SNA interviews about collaboration for coral reef management were conducted with stakeholders in the Indonesian Spermonde Archipelago, South Sulawesi province, and with stakeholders in the Environmental Protection Area Coral Coast on the shores of the Brazilian states of Pernambuco and Alagoas. Weighted social networks were developed for the two case study areas based on the frequency and quality of reported interactions between stakeholder groups. Through the analysis of the structural properties and the composition of the two case study governance networks we discuss their strengths and weaknesses in terms of adaptive and robust marine governance on a regional scale. Hereby, we aim to further the debate on how to address multi-scale problems by adaptive and robust marine governance on a regional sub-national scale.

Keywords: Brazil, Indonesia, Social Network Analysis, Governance

Oral presentation

A model for global cooperative ocean observation networks as the basis for ecosystem-based management, ocean climate research and assessment of ecosystem change

Koslow J.A. and Couture J.

Are current ocean observation networks adequate for ecosystem-based management, ocean climate research and assessment of ecosystem change? A meta-analysis of Pacific Ocean observation programs indicated that readily-measured variables (e.g. temperature, salinity, chlorophyll) are generally well-monitored. However, ecological monitoring, particularly at the species level, remains inconsistent, fragmented, ad hoc, and with critical data access issues still unresolved. As an example, we show that the lack of deepwater micronekton time series leaves the global community unable to assess the potentially massive impact of deoxygenation currently observed in oxygen minimum zones throughout much of the Pacific and tropical oceans.

We propose a model for cooperative monitoring between government fisheries and ocean agencies and academic oceanographic institutions that can provide the basis for fisheries stock assessment within the context of the physical and biological oceanographic environment. Partnerships are also envisaged with global energy producers, who operate increasingly in the coastal and offshore environment. Using the CalCOFI program as a model, we show that such partnerships can provide end-to-end time series for the ocean environment. Comprehensive ocean time series “from winds to whales” serve to underpin the development of robust ocean climate and ecosystem research programs and institutions, as well as ecosystem-based management and effective ocean governance generally. We envisage the development of such programs in large-marine ecosystems throughout the world’s oceans. The cost of such programs may be surprisingly modest, given the value of ocean ecosystem industries and services.

Keywords: Time series, ecological monitoring, end-to-end

Oral presentation

Is there an emerging structure among ocean governance arrangements for the open ocean?

Mahon R., Fanning L., Gjerde K.M., Young O., Reid M. and Douglas S.

The plethora of governance arrangements relevant to the open ocean is often said to be fragmented and uncoordinated. An analysis of 98 global and regional arrangements for open ocean governance of fisheries, pollution, biodiversity and climate change indicates an emerging overall structure. Broadly, the picture is one of two sets of networks: (1) weakly interconnected global-to-regional issue-based networks addressing the above issues, and (2) regional intersectoral complexes/networks which appear, in all but a few instances, uncoordinated.

The global-to-regional issue-based networks are organised around global agreements and facilitated primarily by UN agencies. At the regional level, there appear to be several regions in the world where arrangements pertaining to open ocean issues (and often to ocean issues in general) overlap and interact. These regional clusters of arrangements appear to provide potential arenas for place-based implementation of global arrangements. Fifteen such regional clusters have been identified and reflect a diversity of regional level approaches to intersectoral integration and ecosystem-based management, ranging from relatively well integrated, as in the case of the Pacific Islands Region and Antarctic, to having minimal integration, as seen in several regions.

The spatial coherence of these regional complexes is also highly variable. Frequently, the regional arrangements addressing the issues of concern were developed without reference to other regional arrangements operating in the same area. Some arrangements, notably those involving RFMOs for highly migratory species (HMS), appear in several complexes. For example, ICCAT is included in each of the five Atlantic Ocean complexes. Few of the complexes were found to have clearly identifiable overarching mechanisms for policy development and coordination.

Together these two sets of networks – ‘global-to-regional issue-based’ and ‘regional complexes’ – may provide a useful way of structuring what is usually perceived as a fragmented, unstructured system of ocean governance arrangements. This structure may provide a way for stakeholders to engage with the entire system or specific parts of it by facilitating identification of the kinds of interventions needed to strengthen connectivity within and between networks and where these interventions might be most needed.

Keywords: governance, networks, MEAs, High Seas, ABNJ

Oral presentation

Supporting local economic initiatives in fishing communities to contribute a responsible stewardship and management of sustainable seafood (Nicaragua case in Golfo de Fonseca)

Mendoza H., Rodríguez G. and Mejia S.

Coastal marine resources are a valuable source of life worldwide for millions of people living from their resources, but its irrational exploitation are endangering and reducing coast's natural values and its ability to provide food and other resources. Therefore depletion of fishery resources in marine and coastal areas requires the promotion of new green initiatives and environmentally viable from an economic point of view in coastal communities (those highly dependent on fishing activities). In the context of an initiative funded by European Union and implemented by FoE (Friends of the Earth) Spain and its local partners are running in the tri-national ecosystem of the Golfo de Fonseca (Nicaragua, Honduras, El Salvador), the project ECOPECSA which aims to improve good governance, restoration and sustainably management of mangrove ecosystems, fisheries, protected areas and nearby areas to improve the livelihood of coastal communities.

Two economic alternatives and environmentally friendly have being promoted by ECOPECSA, the production of Pargo Lunarejo in floating cages (*Lutjanus guttatus*) and the production of Conchas Negras (*Anadara similis* and *A. TB*), the first located in the community Aserradores, in the Protected Area (PA) Estero Padre Ramos , and the second in the community of El Rosario (initiative headed by women), in the protected area Cosigüina Volcano, both in the municipality El Viejo, Chinandega. Both projects are contributing to diversify sources of income of 35 families expanding their local capacity to conserve the natural resources of these two protected coastal areas bordering the Gulf of Fonseca, at the same time reducing fishing pressure in this area.

Keywords: Coastal resources, sustainability, economic initiatives, communities

Poster presentation

Environmental NGOs and ocean governance: Linking the public and decision makers in Antarctica's Southern Ocean

Roura R.M., Campbell S., D'Ath E. and Nicoll R.,

Environmental non-governmental organisations (ENGOs) are one of the stakeholder groups in the governance of Antarctica's Southern Ocean, and participate as observers in meetings of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the body that regulates fishing in the region.

Fishing in the Southern Ocean is regulated by the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention). Conservation is a key element of the Convention, and while conservation is defined as to include "rational use", any harvesting shall follow strict conservation principles including the precautionary principle and ecosystem based management. For the past decade, CCAMLR has been working on the establishment of a network of Antarctic marine protected areas (MPAs). This presentation discusses the work of ENGOs to promote the successful completion of these negotiations by CCAMLR, and the impact of the ENGO's public campaign on the CCAMLR MPA process to date.

Antarctica lacks permanent populations that could have an active role in environmental protection in this remote region, and in particular the Southern Ocean is far away from the public eye. Access to CCAMLR discussions is tightly controlled with limited public participation and no media access, and most CCAMLR documents are not publically available. In this context, one of the key roles of ENGOs is to inform the public about developments in the region, and to serve as a link between the public and decision makers.

Formed in 2011, the Antarctic Ocean Alliance (AOA) is a coalition of 30 leading environmental organisations and high profile individuals calling for large-scale protection of critical marine habitats. AOAs' public campaign uses a combination of traditional media and digital platforms such as social media. The campaign has played a pivotal role in raising public and political awareness about protecting the Southern Ocean. The AOA's international media outreach has brought CCAMLR and the protection of the Southern Ocean into the international spotlight for more than two years. In 2013, the campaign generated thousands of media stories globally, with coverage largely led by AOA's campaign messaging.

The collection of over 260,000 signatures from around the world has resulted in increased public pressure on CCAMLR to fulfil their mandate to create a network of MPAs in the Southern Ocean. Further to the petition the AOA's online presence has built a growing, active and engaged community that is holding governments accountable for their actions.

After years of steady progress towards the establishment of a network of MPAs, discussions have slowed since 2012 at the point of making decisions about concrete MPA proposals for East Antarctica and the Ross Sea. Most CCAMLR Members are "already on board", while the consensus of a few others is "critical to success". Given the substantive and growing public interest on this issue it is unavoidable that decision makers will have to reach consensus on MPA adoption. The presentation concludes with a call for CCAMLR Members to listen to public opinion and to adopt ambitious, lasting MPAs that ensure the sustainability of the Southern Ocean.

Keywords: Antarctica, Marine Protected Areas, Environmental NGOs
Oral presentation

Strategic thinking for marine conservation in Antarctica: A case study of the establishment of Marine Protected Areas in the Southern Ocean

Roura R.M.

Baumgartner and Korhonen (2010) defined the notion of “strategic thinking” as characterized by three interrelated and distinct dimensions: strategy process, strategy content and strategy context. Here, we use this framework to examine how strategic thinking is applied to marine conservation in Antarctica, focusing on ongoing negotiations concerning the establishment of a network of Marine Protected Areas (MPA) in the Southern Ocean. We use the term MPA to refer to a range of marine area management options, from multiple use areas to fully protected marine reserves.

The Southern Ocean constitutes approximately 15% of the world’s seas. Fishing in this area is regulated by the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR Convention), which entered into force in 1982. Article II (1) states that the objective of the Convention is the conservation of Antarctic marine living resources. Article II (2) notes that for the purposes of CCAMLR, the term ‘conservation’ includes ‘rational use’, an undefined term that is usually - but not exclusively - understood as harvesting. However, Article II (3) states that any harvesting in the Convention area shall be conducted in accordance with several important conservation principles including the precautionary principle and ecosystem based management.

Overall, the Convention forms a framework that can guide strategic thinking for marine conservation in Antarctica. Since 1982, the body governing fishing in the Convention area - the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), composed by 24 states plus the European Union – has arguably adopted strategic thinking approaches in some of its marine conservation initiatives. These have resulted, inter alia, in reduction in seabird by-catch mortality; taking actions to combat combating illegal, unregulated and unreported fishing; and the protection of benthic vulnerable marine ecosystems.

In 2004 CCAMLR began to address the topic of MPAs, and over the years progress was made through a number of workshops, the adoption of the first MPA in 2009, and the approval in 2011 of a general framework for the establishment of CCAMLR MPAs. Most CCAMLR Members support the establishment of a network of MPAs, a topic that generates substantive public interest worldwide. However, three consecutive CCAMLR meetings in 2012 and 2013 failed to reach consensus on two MPA proposals on the table, covering several million square kilometres in the Ross Sea and East Antarctica. The basic conservation objective of the Convention is in danger of being eroded by increasing fishing interest in the Southern Ocean.

As a whole, the CAMLR Convention and CCAMLR - building on its conservation record - should be able to provide the strategic content and processes that can deliver MPAs. However, progress in Antarctic MPA discussions would require a strategic context in which shared interests in the region, which are the basis for lasting peace, international cooperation and the conservation of the Antarctic marine ecosystems, are given priority over those of individual CCAMLR Members, with long term benefits for all.

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Baumgartner, R. J. & Korhonen, J. (2010). Strategic thinking for sustainable development. *Sustainable Development*. 18(2), 71–75.

Keywords: Southern Ocean, CCAMLR, Marine Protected Areas

Poster presentation

First steps towards suggesting and supporting policies to achieve good environmental status in the Mediterranean and the Black Sea – PERSEUS Project

Papathanassiou E. and Streftaris N.

The PERSEUS FP7 project aims to design and create an effective and innovative research governance framework able to engage scientists, policy-makers and the public, thereby reaching a shared understanding and informed decision-making based on sound scientific knowledge, with particular reference to the MSFD, yet not exclusively restricted to it. PERSEUS is, thus, a unique project expected to produce significant findings and engage all levels of society to support the approval of Good Environmental Status (GES) across the Mediterranean and Black Seas (SES, Southern European Seas).

A definition of the main pressures, processes and issues at risk in open seas and coastal areas, and an analysis of their impact in scientific and socio-economic terms were prepared for the SES regional basins, focusing on issues that threaten the GES. Considering the gap analysis outcome, field studies and process-oriented experiments have been meticulously planned and conducted.

PERSEUS develops tools to evaluate the environmental status using existing and upgraded monitoring and modelling capabilities. A comprehensive inventory on SES ocean observing systems, with quantitative conclusions on observational gaps and needs was delivered, to upgrade and expand the SES observing capacity and address the MSFD monitoring needs. Some gaps are addressed as R/V cruises were conducted, various fixed stations/moorings were upgraded with biogeochemical and acoustic sensors and gliders were deployed. Modelling activities worked on the tools to be implemented for the evaluation of ecosystem properties across the SES. Atmospheric forcing functions, runoff and nutrient river load datasets were produced, while numerical models, of the “Ecosystem/End-to-End perspective”, were applied. Additionally, satellite data provided estimates of surface phytoplankton biomass, primary production and size class composition, also crucial for model validation. Modelling tools on tuna spawning areas and jellyfish dynamics are under development.

The first step to implement the principles and objectives of the MSFD and promote them across the SES was accomplished reviewing the MSFD Initial Assessments. This review on methodologies, criteria, indicator and set references, highlighted that the information was heterogeneous, complex and in some cases incomplete. A gap scoring system quantified the main gap types in order to strengthen the monitoring systems that will be proposed by the states and advice non-EU countries. Results suggested that harmonisation is needed with supporting and decision trees. A similar review of monitoring strategies and policy frameworks takes place in non-EU countries.

PERSEUS worked on the future implementation of adaptive policies and management schemes, in line with the MSFD. The Adaptive Policy Framework (APF), with its interacting components (APF Toolbox and Stakeholder platforms (SHPs)), is being developed via a participatory approach. Five SHPs have been established, four regionally and one at basin scale. The APF Toolbox’s conceptual framework was developed, using a scenario-planning approach to support management schemes. The review on activities providing background information complementary to the APF toolbox outlined the issues of risk of marine

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environmental policy actions. Inventories and critical assessment of the existing foresight analyses and scenario-planning initiatives followed. Policy and institutional marine policy contexts, and economic valuation studies on marine ecosystem services were assessed.

Keywords: Adaptive Policy, Research Governance Framework, GES,

Oral presentation

The EU Integrated Maritime Policy: Challenges and Opportunities for Sharing Ocean Knowledge and Engaging its Communities towards the Sustainable Management of the Ocean in a Setting of Multilevel Governance

Torres de Noronha I.

European coastal sub-national levels (thereafter, regions) have provided key contributions for shaping and implementing the integrated EU Maritime Policy. Empirical research conducted by the author between 2004 and 2012, and supported by a network of over 130 European coastal regions (the Conference of the Peripheral Maritime Regions of Europe, CPMR), described and found evidence supporting the theory that European regions are legitimate elements of a process of international multilevel ocean governance (MLG). The EU ocean policy process was portrayed as a MLG process composed of hierarchical elements (the EU, national and regional levels), or nested governance (Type I of MLG), and functional jurisdictions (Type II MLG), within the EU and in wider international contexts.

In accordance with the major trends of principled integrated ocean management, a management model was proposed to integrate the different levels of the EU governance, actors and activities, including of the EU basins for cooperation. The model is driven by the ecosystem approach, subsidiarity, and the EU's objective of sustainable development, which is inclusive of the principle of environmental protection. Roles for the regions were recommended, in particular the development of a knowledge-sharing environment, where at the scale of the marine-ecosystem, research, knowledge and other activities would be shared, networked and concentrated, independent of political barriers and boundaries, facilitating the dialogue between researchers and decision-makers toward enhanced efficacy.

For implementation of the EU Maritime Policy, several EU basins were delimited. The EU Atlantic Basin and Strategy touches several marine ecosystems and 5 countries (Ireland, France, Portugal, Spain, UK). The EU Atlantic Basin includes over 300 ocean related research institutions, a plethora of governmental, non-governmental actors and users, which produce and/or use ocean knowledge. In addition to the ones endogenous to this geography, many other externals produce knowledge related to these marine ecosystems.

How to keep track of such information and knowledge? How and where to find particular expertise to further implement the ecosystem approach with efficacy? Knowledge fragmentation is a challenge to research and decision-making communities in finding, collaborating, and synthesizing the necessary knowledge to address complex socio-ecological issues for implementing the ecosystem approach, enhancing ocean governance and sustainable ocean.

The current advances in informatics and global internet solutions provide opportunities to enhance connectivity, promote the exchange of knowledge and integration across disciplines and scales, and improve research, management and decision-making practices.

The Future Ocean Alliance™ (FOA) was created with the goal of improving these issues globally. FOA aims to “use innovative informatics to build an inclusive community – a global ocean knowledge network- able to address emerging ocean governance issues promptly, efficiently, and fairly.” For that purpose, FOA aims to strengthen the research and science-policy dialogue on ocean governance by facilitating and promoting the collaboration

Session D2: Communities of practice

and integration of existing knowledge networks to examine and improve practices in ocean governance, integrated ecosystem assessment, resource management and discipline-based informatics. FOA will seek to do so at all scales, to enhance the sustainable development of the ocean from the local to the global level.

Keywords: Multilevel governance, Knowledge, Networks, Ecosystem approach, Integrated management

Oral presentation

Why do We Need the Future Ocean Alliance? Defragging the Global Ocean in the Context of Ecosystem Based Management

Torres de Noronha I.

The Future Ocean Alliance (FOA) aims to build a single ocean community, connected across scales and disciplines, that engages proactively in ecosystem based management by producing and integrating knowledge into governance processes to ensure a healthy and sustainable ocean. FOA will be doing with support of innovative informatics to build a global community – a global ocean knowledge network- able to address emerging ocean governance issues promptly, efficiently, and fairly.

FOA is an association that brings into an alliance organizations and individuals dedicated to integrating knowledge and governance processes at early stages of decision-making at all scales to enhance ocean sustainability in the face of cascading changes that are threatening the health of the world's marine systems from the local level to the global level. To this end, FOA will act as a connector and catalyst for collaboration among diverse communities of practice with strong ocean interests. These collaborations span at all spatial scales from local, national, regional, to global. FOA's constituency includes all ocean actors ranging from individuals, researchers, and decision-makers ranging from policy, public administration, research managers, businesses, and civil society groups.

As such, FOA will promote a network of networks, acting across and within disciplinary, organizational, geographic and international boundaries, to understand who is doing what, where, how, why, and what for?, and to:

- Deliver an ocean research agenda focused on knowledge for sustainable development of the ocean
- Develop a coordinated global knowledge network for the ocean, inclusive of the multiple scales and levels
- Promote sharing and access to curated knowledge and expertise
- Analyze and disseminate the results of research pertaining to questions into ongoing governance initiatives;
- Launch concerted efforts to elicit and frame cutting-edge questions that will serve to deliver solutions with all those concerned with sustainable management of marine ecosystems.

At the Rio+20 Conference (2012), the ocean community acknowledged the need to concentrate efforts to enhance ocean and coastal management and governance, including capacity development, and the need to address emerging issues. Rio+20 delivered various global coordinating initiatives addressing ocean policy. However, none addressed the needs for coordinated knowledge, management and governance.

The need for a coordinated mechanism to enhance ocean governance, management and knowledge has been acknowledged and discussed in numerous other fora over the past 20 years (Rio 92). Since 2011, members of the research and decision-making communities have been meeting at international venues to consider responses to this challenge. The aftermath of Rio+20 culminated with the set up of FOA in Lisbon, aiming to provide such coordination engine and to help pushing the formal system toward the necessary adjustments.

Keywords: governance, knowledge, network, informatics

Oral presentation

The Future of the Ocean: Knowledge, Action

Young O.R.

What roles do knowledge and knowledge systems play in making, implementing and evaluating decisions about issues of ocean governance. Using the concept of the policy cycle, this presentation argues that (i) the contributions of knowledge differ from one stage of the cycle to another and (ii) the determinants of the effectiveness of these contributions are specific to each of the stages of the cycle. We tend to direct attention to the role of science at the stage of making unique choices (e.g. whether to go forward with the Revised Management Procedure in the International Whaling Commission, whether to establish MPAs in the Ross Sea under the Convention on the Conservation of Antarctic Marine Living Resources, whether to ban heavy fuel oils in the Arctic under the terms of the Polar Code developed by the International Maritime Organization). But this is a process in which other considerations regularly play a powerful role and the contributions of knowledge are particularly circumscribed. By contrast, the roles that knowledge plays in other stages of the policy cycle receive far less attention. We ought to devote more thought to the factors that determine the effectiveness of knowledge in shaping policy agendas and in organizing the implementation of choices rather than bemoaning the limited roles of knowledge and knowledge systems at the stage of making unique choices.

Keywords: policy cycle, agenda formation, choice, implementation

Oral presentation

Session D3: Responses of society to marine and global changes as a core mandate for IMBER: ways forward

Oral presentations

Wednesday 25 June, 11:00-12:30 Parallel session 4

Topic: Integrated Approaches/Methods

Chair: Alida Bundy

Room K1

Time	Presenter	Title
11:00-11:20	Perry, Ian	Towards an operational typology of marine resource crises and human responses
11:20-11:40	de Kok, Jean-Luc	Participatory modelling with fuzzy cognitive maps - A case example for the vulnerability of aquaculture for climate change
11:40-12:00	Richards, Russell	Stakeholders and expert opinion: Using iPad Apps to better parameterize Bayesian belief network models
12:00-12:20	Galbraith, Eric	Future fish harvest in a coupled Earth System-Economic model
12:20-12:30		Discussion

Wednesday 25 June, 14:00-15:30 Parallel session 5

Topic: Fisheries/Aquaculture and global change

Chair: Thomas Therriault

Room K1

Time	Presenter	Title
14:00-14:20	Criddle, Keith	Trends in time series observations of human dimension indicator data for the North Pacific ecosystem
14:20-14:40	Guillotreau, Patrice	How to cope with mass mortality of bivalves?
14:40-15:00	Gasalla, Maria	How costly is presently to fish in the South Brazil Large Marine Ecosystem? Common-property resources and fishing industry viability
15:00-15:20	Chuenpagdee, Ratana	Comparative analysis of fisheries 'impacts' using socio-economic indicators
15:20-15:30	All	Poster presentations (2 min. each) and discussion

Session D3: Responses of Society

Thursday 26 June, 14:00-15:30 Parallel session 7

Topic: Ecosystems (sensu lato)

Chair: Ian Perry

Room K2

Time	Presenter	Title
14:00-14:20	Wakita, Kazumi	Discrepancies between utility of marine ecosystem services and behavioural intentions for marine conservation in Japan: Socio-psychological and economic insights
14:20-14:40	Therriault, Thomas	Large-Scale Ecosystem and Societal Responses: The PICES FUTURE Program
14:40-15:00	Glaeser, Bernhard	Global change and local threats: From coastal and marine typologies to governance
15:00-15:20	Li, Yinji	Responses of Society to Emerging Fisheries-Tourism Conflicts-A Case study of Onna story, Japan
15:20-15:30	All	Discussion

Friday 27 June, 10:30-12:00 Parallel session 8

Topic: Ecosystems (sensu lato)

Chairs: Bernhard Glaeser and Alida Bundy

Room K2

Time	Presenter	Title
10:30-11:00	Fulton, Beth	Humans as barriers to adaptation - a modelling perspective
11:00-12:00	Panel: Thomas Therriault, Edward Allison, Ingrid van Putten	Lessons Learned and Future Directions - Open discussion with audience

Poster Presentations

Wednesday 25 June, 17:30, Poster Session 2

ID	Presenter	Title
D3.P1	Perry, Ian	A statistical approach to the development of ecosystem indicators for multiple pressures in the Strait of Georgia, Canada
D3.P2	Blasiak, Robert	Challenges of Forming and Maintaining Coalitions: A Game Theory Approach to Transboundary Management of Nomura's Jellyfish (<i>N. nomurai</i>)
D3.P3	Garcia Morales, Gisela	Management strategy for beaches: the importance of user perceptions on four beaches of Sonora, Mexico

Challenges of forming and maintaining coalitions: A game theory approach to transboundary management of Nomura's Jellyfish (*Nemopilema nomurai*)

Blasiak R. and Yagi N.

Until 2002, blooms of Nomura's jellyfish (*Nemopilema nomurai*) in the Sea of Japan occurred roughly every 40 years, a trend that has since accelerated to an almost annual event. Uye (2007) cited the 2005 bloom as possibly the largest ever, during which every day an estimated 300-500 million *N. nomurai* medusae entered the Tsushima Strait, separating Japan from the Korean Peninsula. Total economic losses were estimated at JPY 30 billion, fuelling concerns about the impacts of jellyfish blooms in what is one of the world's most productive fisheries. Existing literature and testing suggests that the main habitat of *N. nomurai* prior to its medusa phase is located within the EEZ of China, the DPRK and ROK. Adverse economic impacts of jellyfish blooms could therefore be a driver for engaging in cooperative trans-boundary management.

The aim of this research is to adapt existing cooperative game theory models (most of which focus on single species and assume perfect information) to predict the possibility of cooperation on managing threats to marine fisheries. Traditionally, coalitions of players managing resources are considered stable if the benefits of cooperation over a discrete time period outweigh any benefit of defection (minus any punitive responses). Hypothesizing that the same model can be inverted as a predictive tool for promoting cooperative management of threats to marine fisheries, the prospects for a transboundary approach to mitigating the impacts of *N. nomurai* on corresponding fisheries will be considered.

Keywords: game theory, transboundary management, cooperation, jellyfish

Poster presentation

Comparative analysis of fisheries 'impacts' using socio-economic indicators

Chuenpagdee R.

As part of an ecosystem approach to fisheries management, great effort has been made to evaluate the ecological state of the fisheries and to determine the impacts of fishing on ecological system. Less is known, however, about the contributions of fisheries to livelihoods and wellbeing of people depending on fisheries resources. We argue that management goals can be better set, if these 'positive' impacts are explicitly considered along with other aspects in planning decisions, and also in the monitoring and evaluation of whether policy goals are achieved. While recognizing the complexity of the fisheries ecosystems, we propose a set of simple indicators to capture key essence of fisheries management and governance, along with those related to economic (contribution of fisheries to broader society) and social importance (wellbeing and resilience of fisher communities) of fisheries. We explore the relationship between these indicators for several ecosystems from developed and developing countries around the world. Using multivariate analyses and relating results to other indicators, our aim is to evaluate how well these indicators differentiate and describe different ecosystems, and how well they capture the important human dimensions. Our results illustrate the utility of this approach in bridging the gap between ecological and social objectives in ecosystem management.

Keywords: indicators, ecosystem, fishing impacts, livelihood contribution

Oral presentation

Trends in time series observations of human dimension indicator data for the North Pacific ecosystem

Criddle K.R. and Makino M.

The North Pacific Marine Science Organization (PICES) Section on Human Dimensions of Marine Systems (S-HD) has developed a list of variables that characterize human dimension aspects of the state of the North Pacific ecosystem. This presentation describes spatial and temporal trends in time series observations (TSOs) of these indicator variables and reports on exploratory analyses that endeavor to attribute the observed trends to observed variation in environmental, economic, social, and political drivers.

Keywords: human dimension indicators, North Pacific

Oral presentation

Participatory modelling with fuzzy cognitive maps - A case example for the vulnerability of aquaculture for climate change

de Kok J.L., Engelen G., Tiller R., Bailey J. and Richards R.

The goal of the EU-FP7 project OCEAN-CERTAIN is to analyze the consequences of climate change on the interaction between the oceanic food web and the biological pump, including the social response to different adaptation strategies available to cope with these changes. Participatory workshops with local stakeholders and marine managers will help identify the problems, underlying causes and potential solutions for case studies in the Northern Atlantic, Mediterranean and Patagonia. A decision-support system will be developed to visualize different scenarios and management options in more detail, using a system dynamics model to capture the feedback mechanisms resulting from the interaction between the biogeochemical and social processes at the level of detail needed for strategic scenario analysis. However, the data requirements and complexity of the underlying models can limit their usefulness for direct application in an interactive setting with stakeholders. Fuzzy Cognitive Mapping can help bridge the gap between the qualitative participatory exercises and quantitative systems dynamics modelling. Fuzzy Cognitive Maps, or FCMs, are directed causal graphs and were introduced as a simplified way to describe the causal feedback of systems of arbitrary complexity [1]. Stakeholders, managers and scientists can combine their expertise and different viewpoints, resulting in a graphical representation of the key variables and linkages. The next step is to take the analysis one step further by assigning “fuzzy” weights to the system causalities. The resulting FCM can then be used to analyze and compare scenarios which may differ in terms of the initial conditions and driving forces of the system. Here, we present an application of Fuzzy Cognitive Mapping to the case of aquaculture in Norway. Aquaculture along the Norwegian coast is booming and doubled since 2004 with revenue of more than 3.7 billion Euros in 2012 [2]. The rapid expansion, economic significance, vulnerability for climatic and non-climatic stressors and potential conflict with other coastal use functions such as wild capture fisheries [3] make aquaculture an interesting case example for testing the usefulness of FCMs. The presentation focuses on the methodological challenges of the design and application of FCMs for scenario analysis.

[1] Bart Kosko. Fuzzy Cognitive Maps. *International Journal of Man-Machine Studies* 24, 65-75, 1986.

[2] Norwegian Ministry of Fisheries and Coastal Affairs. www.fisheries.no

[3] Rachel Tiller, Rebecca Gentry and Russell Richards. Stakeholder driven future scenarios as an element of interdisciplinary management tools; the case of future offshore aquaculture development and the potential effects on fishermen in Santa Barbara, California. *Ocean and Coastal Management* 73, 127-135, 2013.

Funded by Ocean Certain project EU-FP7 Grant 603773.

Keywords: Climate Change, Fuzzy Cognitive Mapping, Aquaculture

Oral presentation

Humans as barriers to adaptation – a modelling perspective

Fulton E.A., Gorton R., Johnson P. and Griffith G.

Integrated end-to-end models incorporating the complex mix of cumulative pressures placed on the world's oceans are increasingly used to explore alternative futures. Work in highly dynamic regions, hotspot regions of global change such as southeastern Australia, is providing insight into how the cumulative pressures may shape future ecosystems and what may be some of the greatest barriers to adaptation. By comparing the relative role of physical drivers, ecological mechanisms - like acclimation, evolution and shifts in food webs – as well as human responses, it is clear that in most cases human responses represent some of the greatest barriers to negotiating global change with the least disruption to marine ecosystems. While simulations show that integrated management of marine ecosystems provides the most robust form of management, some of the cultural, economic and behaviour changes that would require of the societies that use Australia's marine ecosystems means that implementing the requisite changes in reality may not be a simple exercise. Moreover, even if managers successfully implement integrated ecosystem management it is likely there will not be an end to the pressure those management bodies experience. Sociobiologists, evolutionary psychologists and behavioural economists all suggest that to a large degree humans desire a high degree of certainty and draw on past knowledge to give insight into current and future states. Simulations of potential futures for southeastern Australia indicate that unfortunately high variability indicative of transitioning ecosystems is unlikely to provide much succour for those desiring certainty, just as shifts in ecosystem properties and thresholds mean that historical knowledge and past best practice will not be as useful as it once was.

Keywords: ecosystem response, end-to-end models, adaptation, socioecology

Oral presentation

Future fish harvest in a coupled Earth System-Economic model

Galbraith E., Carozza D. and Bianchi D.

The production of fish biomass for harvest depends on the supply of energy to the ecosystem through photosynthesis, which depends on the physical environment, and the transfer of that energy to commercial fish species. In addition, the heavy pressure of industrial fisheries on fish biomass can alter the regeneration of fish biomass by decreasing egg production, and by removing young fish, thereby preventing their growth to large fish. We present a model that represents these processes as a coupled physical-biogeochemical-ecological-economic system. We predict primary production in all grid cells of a global model from the physical ocean state, and make this energy available to a size-structured ecosystem using allometric scaling and a simple growth parameterization. Fishing effort is determined in all grid cells using a simple open-access model, with effort increasing or decreasing in response to average profit. Although highly idealized, this model reproduces aspects of the global fishery reasonably well. We compare historical catch data to what the model predicts, and compare this to future catches using the CMIP5 model projections of ocean temperature and primary production.

Keywords: biogeochemistry ecosystem fishery global climate

Oral presentation

Management strategy for beaches: the importance of user perceptions on four beaches of Sonora, Mexico

Garcia-Morales G., Arreola Lizarraga J.A., Ortega Rubio A., Mendoza Salgado R., Garcia Hernandez J. and Rosales Grano P.

In many areas of the developing world, rates of population growth and urban populations are larger in the coastal zone and in recent years has added a base of scientific knowledge about the ecological importance that represents this area, adducing increasingly objectives to guide decisions in terms of conservation, leading to a comprehensive and holistic, whose purpose is to avoid the huge environmental and social costs, which has resulted in the massive and rapid transformation of the coast and hence the water pollution from the beaches. Tourism and recreation at beaches like factor in the Mexican economy is no doubt, however, in Mexico despite government efforts, urban development in the coastal zone has been a failure in terms of planning, this is because poor implementation of schemes characterization and evaluation, to facilitate planning and proper management to meet the specific needs of each beach to prevent spoilage and maintain services that are derived from this environment. In Mexico, the beaches have begun to be reassessed before the imminent scenario be impacted and / or modified by rising sea levels, and effects of human activity, using assessment tools that consider aspects to measure the quality of the beaches and continuous improvement of the same, as their importance lies in these two aspects, which promotes the introduction of measures to improve sanitary conditions, infrastructure, environmental protection and the future may be candidates for certification. An example of this in our country is the standard (NMX -AA -120- SCFI , 2006) to certify the quality of beaches in terms of water quality and which also includes measures to protect the environment in the tourist beaches of Mexico. Also, in recent years have proposed methodologies for characterizing the beaches and another aspect that has been mentioned, refers to the importance of including the views of the users in the evaluation schemes and planning beaches, as it is considered the most important to guide process improvement thereof, together with infrastructure design plans that meet their uses and management element . In this sense, this study is aimed at creating management strategies based on comprehensive assessment of the four beaches of Sonora, Mexico considering the perception of users on the same resources. The knowledge generated will be useful for comparative purposes of interest in the management of beaches, since it has been found that despite the proximity of the beaches studied, have different coastal settings, are active beaches throughout the year and are visited by different types of users which have provided important information to generate strategies for handling them.

Keywords: Beach, Management, research, user perceptions

Poster presentation

How costly is it presently to fish in the South Brazil Large Marine Ecosystem? Common-property resources and fishing industry viability

Gasalla M.A., Rodrigues A.R. Gandini F.C., Pellegrinelli A., Santos M.V. and Raggi, P.A.

Marine fisheries are complex systems characterized by reciprocal interactions between “individual” fishing activities and the harvested common-property resources under particular conditions of the ecology in the sea. However, most of the challenges of real world fisheries management seems not to be the understanding of the ecology of life per se but the human’s use of these resources for his own purposes and benefits. Thus, understanding how the catches in proportion to the effort to yield a satisfactory living to fishermen behave in a particular system is essential to propose sound policies to avoid multi-criteria depletion. The chief aim of this paper is to examine the current costs of fishing by the different fleets operating in the South Brazil Shelf. The cost structure data collection and analysis follow methodology already purposed (Gasalla et al 2010) while the benefits are defined in a distinct fashion by integrating social-ecological-economics dimensions. The most important fishing fleets in the LME are covered. Fishing cost varies depending on the type of fishery, and the gear and vessel employed. The regional fishing industry appear to face several challenges such as space-competing industries at sea, marine protected areas, biodiversity conservation needs, global changes, the increase of fuel price, and poor fishery management. Therefore, to understand the economic viability of the different fleets, it is crucial to have information on the cost of fishing, which is the main survey of an ongoing research project in Brazil. It is expected that it will allow assessing the current economic status of the regional fisheries sector, a comparison of the economic performance of fisheries under different options, and the common-property resources state in contrast to fishing viability.

Keywords: fishing costs, Brazil, fleets, economic viability

Oral presentation

Global change and local threats: From coastal and marine typologies to governance

Glaeser B.

Coasts and oceans have gained ever more importance during the last decades. Roughly two thirds of the human population lives, works and produces on coasts. Oceans and coasts are major sources of food, minerals and other resources and services. Oceans are the “unknown planet” where a census of marine life was launched. Coasts and oceans represent a maximum of biodiversity. They also represent political and economic vested interests, which produce conflicts.

Economic costs and social hardships induced by global change, such as climate change, appear at the local level. The important decisions, activities and measures usually occur at higher, mostly the national levels. Internationally, an uneven distribution of interests, benefits and costs relating to climate change is evident. Climate impacts, poverty and social justice are interlinked across spatially nested, hierarchical levels. The uneven distributions of wealth can be understood as nested hierarchies which are reproduced at the various levels of the socially and ecologically organized global system, beginning at the local up to the global level.

Hierarchically organized systems can be identified when regarding the impacts of global change, including climate and social change. These social-ecological systems link the pressures exerted by climate change to social impacts for whole societies, groups or individuals. The political responses at the national or regional level labor at finding economic, social, ecological and technological solutions to meet the problems encountered. Such attempts may occur independently of whether the causal chain from drivers producing global changes via the observed or felt pressures down to the local ecological changes and social impacts has been scientifically established.

This presentation proposes to study coastal and marine social-ecological environments at different scales on different levels. This is exemplified by a case study from Indonesia. Scales are the space, time or governance related dimensions. Levels are located at different positions on a scale and include the global level as well as local to regional level comparative case studies. Social-ecological sustainability problems are caused by drivers from multiple levels of the earth system.. A coastal and marine typology is presented to understand and compare the ecological, socio-cultural and economic aspects of coastal and marine systems. On that basis, science should be linked to policy. Such a process involves different levels again, on a governance scale: from local management decisions to national lawmaking and international-global governance production and producers, such as the European Union or the United Nations Organization. Distributional imbalances on different levels can be identified as climate change impacts: the “climate divide”.

Keywords: Global change, social-ecological systems, Indonesia, typology

Oral presentation

How to cope with mass mortality of bivalves?

Guillotreau P., Bundy A., Cooley S., Defeo O., Le Bihan V. and Pardo S.

In many parts of the world and particularly during the last decades, commercial (harvested or cultured) bivalves have been hit by mass mortality episodes due to climatic and/or anthropogenic stressors which are not always clearly understood in their causes and consequences. Such phenomena resulted in various responses from fishers or farmers. In the present study, several commercial shellfish from different parts of the world affected by mass mortalities were analyzed by the IMBER-ADApT (Integrated Marine Biogeochemistry and Ecosystem Research - Assessment based on Description, Responses and Appraisal for a Typology) approach in order to assess collective and individual responses of the stakeholders (users, managers, states) to these events. We also assessed the impacts or consequences of these perturbations on the natural, social and governing systems. The comparative analysis provided a basis for the appraisal of adaptive responses and their likelihood of success by combining the characteristics of their natural, social and governance settings. Common stressors increasing the vulnerability of shellfish ecosystems to mass mortalities were identified (e.g., increasing sea surface temperature and salinity, nutrient-enriched waters, acidification), but cannot explain by themselves why social responses may succeed or fail to sustain the local farming or fishing industries. Social capital of the local communities and governability were key factors of resilience and adaptation to environmental changes affecting social-ecological marine systems.

Keywords: social ecological system, adaptive response, IMBER-ADApT

Oral presentation

Responses of society to emerging fisheries-tourism conflicts - A case study of the Onna story, Japan

Li Y., Lou X. and Harada S.

Onna Village which is located on the west coast of mainland Okinawa, used to be a village subsisting on agriculture and fisheries, until its tourism boom arrived after an Ocean Expo held in 1975. With the emerging tourism, the conflicts between fisheries and the new industry-“red clay outflow” and “coastal use” became a serious social issue in the village from the mid 70’s to 80’s. The Fisheries Cooperative Association (FCA) of Onna village played an important role in solving these problems and leading the village to a drastic economic growth with balanced use of coastal area and the resources. This study firstly clarifies the coastal environmental changes and its generating mechanisms in the village, secondly illustrates the responses of the village to the emerging issue and analyzes its rationality and efficiency, finally discusses fishery’s role and function in dealing with marine and global change.

Keywords: Fisheries, Tourism, “Red clay outflow”, “Coastal use conflicts”, Fisheries Association

Oral presentation

Towards an operational typology of marine resource crises and human responses

Bundy A., Chuenpagdee R., Cooley S., Defeo O., Glaeser B., Guillotreau P., Isaacs M., Makino M. and [Perry R.I.](#)

Increasingly we are beginning to understand that (a) there are many linkages and interactions within marine ecosystems and between marine ecosystems and various components of human society, (b) these interactions can take different forms and (c) we need to take an holistic, interdisciplinary approach to many of the challenges facing marine ecosystems and their dependent human communities. These linked social and ecological systems are subject to change and when they change in unexpected ways which impact human livelihoods and well-being, the changes are usually described as crises. Such crises require a response from the human governing system to mitigate the impacts of the change. To date, there have been few attempts to develop a structured approach to review and understand what governance responses are effective (and which are not effective) for different types of marine ecosystem changes and human social system situations. Using the IMBER-ADApT (Assessment based on Description, Responses, and Appraisal for a Typology) framework, we describe the development of a typology of marine resource crises and human (governance) responses, for linked marine social and ecological systems. Using a selection of marine case studies, we describe how they can be used (1) as a simple inventory of the types of crises, the human social contexts, and the governance responses (and whether they were successful); and (2) to develop a typology that identifies and groups similar crises, human contexts, and responses. We discuss the key characteristics that might be used as 'entry points' into the inventory and as criteria for the typology, and show how these can be used to develop the typology (and some of the difficulties). The goal is to produce an operational system to assist and guide cost-effective policy and governing responses to marine resource crises that allows users to quickly identify which responses have worked (and which have not worked), and why, in similar situations elsewhere.

Keywords: Human Dimensions, Typology, marine environmental crises

Oral presentation

A statistical approach to the development of ecosystem indicators for multiple pressures in the Strait of Georgia, Canada

Perry I. and Masson D.

A Driver-Pressure-State-Impact model of the Strait of Georgia, Canada, was developed as a framework to characterise the low frequency temporal responses of this system to natural and anthropogenic pressures since 1970, and to identify suitable indicators of these changes. Thirty-seven time series were assembled for multivariate statistical analyses. Principal component analyses identified regime-like shifts corresponding to those generally accepted for the NE Pacific. Redundancy analyses identified significant relationships in which the multiple natural and human explanatory driver/pressure variables accounted for 72% of the variability of the state/impact response variables. Partitioning this variance among the natural and human drivers/pressures attributed 4% to the natural drivers/pressures alone and 16% to the human drivers/pressures alone, but 53% to the interactions between natural and human drivers and pressures. Both sets of driver and pressure variables (natural and human) are necessary to account for the patterns of variability of the state and impact variables in the Strait of Georgia. Redundancy analysis identified a reduced set of driver/pressure variables which accounted for a large proportion of the variability in the state and impact response variables: sea surface temperature, wind speed, the North Pacific Gyre Oscillation index, human population surrounding the Strait of Georgia, recreational fishing effort, and the number of hatchery releases of Chinook salmon (*Oncorhynchus tshawytscha*) into the Strait. These six explanatory variables are proposed as leading indicators for low frequency changes (regime shifts) in the Strait of Georgia marine social–ecological system for use within a broader monitoring program.

Keywords: ecosystem indicators, Canada, social-ecological system

Poster presentation

Stakeholders and expert opinion: Using iPad Apps to better parameterize Bayesian belief network models

Richards R.G., Tiller R., Bailey J., Salgado H., Olsen Y. and Ardelan M.V.

The EU-FP7 project OCEAN-CERTAIN aims to investigate the impact of climatic and non climatic stressors on the food web and the connected biological pump and the important feedback mechanism. Within this multi-disciplinary project, Work Package 3 (WP3) is investigating the human dimensions of the socio-ecological system (SES) and how these are both impacted by, and impact on, the marine food web. This focus on the human dimension of these stressors and system responses means that the experiences of stakeholders often plays an important role when assessing adaptation options and/or the determinants of adaptive capacity. Numerical methods such as Bayesian Belief Network (BBN) modelling can provide a means of eliciting, coalescing and quantifying this 'expert opinion' in a probabilistic framework (i.e. explicitly accounting for uncertainty). Furthermore, through the underlying framework of Bayes theory, this expert opinion can be integrated with data arising from other disciplinary areas (e.g. ecology, fisheries, marine chemistry etc). Whilst this participatory modelling approach engenders stakeholder confidence in the development process, parameterising these BBNs remains a key challenge. Specifically, the experiences of the authors have shown that the process of obtaining conditional probabilities from the stakeholders can be difficult and prone to inconsistencies. To address this issue, OCEAN-CERTAIN is using computer tablet technology and its interactive capabilities to develop an application (App) to obtain these conditional probabilities. This App has been developed based on the experiences of the research team in climate change and fisheries research and through field-testing at different stages of the design process. We will present details on the App including its development and the early outcomes of its application in field studies associated with the OCEAN-CERTAIN project. Furthermore, we will also contextualize the importance of using this approach in parameterizing expert-based BBNs by comparing and contrasting it with more traditional approaches. Overall, the development of this App and usage of this rapidly emerging technology in stakeholder engagement process will lead to significant improvement of using BBNs as a methodological approach in the OCEAN-CERTAIN project.

Keywords: Stakeholders, Participatory-modelling, Bayesian-Networks, iPad, Apps, climate change

Oral presentation

Large-scale ecosystem and societal responses: The PICES FUTURE Program

Therriault T.W., Perry R.I., Makino M. and Keith Criddle

It is now widely accepted that marine ecosystems are rapidly changing in response to both natural and anthropogenic drivers and these ecosystem changes are impacting the societies that depend on them. Most small to medium scale research programs aim to better resolve either the ecological mechanisms of change or socioeconomic impacts of change but rarely both. Within the North Pacific Ocean, the North Pacific Marine Science Organization (PICES) is approaching the mid-point of a decade-long integrative science program entitled “Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems (FUTURE)”. The primary goal of this large scale international, integrative program is to link these ecological and socioeconomic systems in a way that is useful for sustainable utilization. PICES has a rich history of increased scientific understanding of mechanisms and processes occurring in North Pacific marine ecosystems and the PICES FUTURE program aims to build on this history to specifically address the question “How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?” As an organization, PICES has over 20 years experience conducting large-scale joint research projects, but incorporating human dimensions is a new element for PICES. To embrace this change and significantly advance FUTURE, human dimension-related themes are being addressed by new activities. For example, to compliment ecosystem indicators of change PICES has been developing a suite of marine-related human dimension indicators that will allow the first large scale comparison of changes in marine-dependent human communities and societies around the North Pacific due to global change. This will allow PICES member nations to identify the most significant challenges/needs of member countries and to devise appropriate responses. In this presentation we introduce and discuss the concepts and implementations of PICES research with special emphasis on human dimensions embedded in the PICES FUTURE science program and convey preliminary findings. The ultimate goal is to provide a framework that can lead to sustainability via an integrated, interdisciplinary marine social-ecological systems approach.

Keywords: North Pacific, global change, social-ecological system

Oral presentation

Discrepancies between utility of marine ecosystem services and behavioural intentions for marine conservation in Japan: Socio-psychological and economic insights

Wakita K., Shen Z., Oishi T., Yagi N., Kurokura H. and Furuya K.

Marine ecosystem services provide various benefits to people, which eventually contribute to human well-being. Ensuring continuous receipt of the benefits of marine ecosystem services is one of the most important issues for sustainable development. Considering the importance of marine ecosystem services, this study explores utility of marine ecosystem services and how it influences behavioural intentions for marine conservation, taking Japanese residents as an example. In exploring this, we use “indispensability” as a key concept. Building on a presumption that the higher the perceived indispensability, the greater the utility, a hypothesis has been developed that the higher the indispensability, the greater its influence on enhancing behavioural intentions for marine conservation. We conduct a factor analysis and test a structural equation model correlating perceived indispensability and behavioural intentions based on responses to questionnaires from 814 residents in Japan. The factor analysis identifies three constructs which we name “Essential Benefits”, “Indirect Benefits”, and “Cultural Benefits”. Based on the indicators gained from the analysis, perceived indispensability is high in order of “Essential Benefits”, “Indirect Benefits”, and “Cultural Benefits”. On the other hand, the structural equation model clarifies that the influence on behavioural intentions for marine conservation is high in order of “Cultural Benefits” and “Essential Benefits”. “Indirect Benefits” does not have a significant causal relationship with behavioural intentions, statistically. These results imply that in order to increase support from the general public for marine conservation in Japan, it would be more effective to stress measures that enhance “Cultural Benefits” of marine ecosystem services than measures stressing their indispensability. Furthermore, we presume that the above discrepancies between perceived indispensability and its influence on behavioural intentions for marine conservation would be explained by the “scarcity principle”, which is used in both economics and psychology; that is, the discrepancies could be generated because the Japanese residents perceive “Cultural Benefits” as scarce, while “Essential Benefits” as abundant and secured. Building on the scarcity principle, it could be assumed that the utility of marine ecosystem services would fluctuate in accordance with the scarcity of the services in their places of residence. Further research in different geographical settings and marine environmental status is required to deepen understandings on causal relationships between perceived indispensability of marine ecosystem services and behavioural intentions for marine conservation and to examine validity of our presumption above.

Keywords: marine ecosystem services, socio-psychological approach, utility

Oral presentation

Session D4: Future Oceans' stewardship: roles, responsibilities and opportunities in small-scale fisheries

Oral presentations

Wednesday 25 June, 16:00-17:30 Parallel session 6

Chair: Ratana Chuenpagdee

Room D4

Time	Presenter	Title
16:00-16:20	Ho, Nga Thi Thanh	Small Scale Fisheries Management in Vietnam: Co-management for Sustainability
16:20-16:40	Rivera, Antonella	Is co-management an option in Europe?: Case study of the Asturian (N. Spain) gooseneck barnacle fishery.
16:40-17:00	Mahon, Robin	Identifying supportive governance structures for the enhancement of stewardship in Caribbean coral reef fisheries
17:00-17:20	Chuenpagdee, Ratana	Local stewardship for sustainable future: examples from Thailand and Canada
17:20-17:30	All	General Discussion

Local stewardshi for sustainable future: Examples from small-scale fisheries in Thailand

Suebpala W., Yeemin T., Sutthacheep M., Satumanatpan S., Juntarashote K., Hart K. and Chuenpagdee R.

Fishery resource depletion is a worldwide phenomenon, caused mainly by overfishing, destructive fishing practices, pollution, environmental change, and mismanagement. Small-scale fishing communities are particularly vulnerable to the situation, given their high dependency on the resources. It is therefore within their interests to maintain the integrity of the marine ecosystem through various means, including environmental stewardship. Knowing whether stewardship takes place, in what form, and why, as well as the extent to which it contributes to sustainability and viability of local communities is beneficial for policy development and governance aiming to secure their future. We examine these questions in two coastal provinces of Thailand, Trat in the east and Satun in the southwest, using key informant interviews. Our findings illustrate that, in both cases, small-scale fishers have high level of awareness about the causes of fisheries resource depletion and have initiated many community-based stewardship projects to reverse the trend. Most projects emphasize conservation and rehabilitation of coastal ecosystems, especially mangrove reforestation and enhancement of fisheries abundance through protection of female and juvenile marine organisms. Key enabling factors for stewardship efforts are social cohesion and community leadership. Financial support and scientific expertise from government departments, non-governmental organizations and academics are also crucial for the success of these initiatives. While there is no clear evidence about the direct relationship between environmental stewardship and community viability, many socio-economic characteristics of the communities are good indicators of their ability to maintain their preferred way of life and to overcome future challenges.

Keywords: Environmental Stewardship, small-scale fisheries, Thailand

Oral presentation

Small Scale fisheries management in Vietnam: Co-management for sustainability

Ho N.T.T., Ross H. and Coutts J.

Small scale fisheries provide food, livelihood and employment for millions of people throughout Vietnam. During the last two decades, under pressure of rapid development of aquaculture, fishing technology and growth of population there has been depletion of fish stocks, a degradation of environment and conflicts between resource users. These problems make small scale fishers vulnerable. In that context, donor funded agencies have supported Vietnam to build co-management for effective management of fisheries in Vietnam. This paper examines the emergence of fisheries co-management in Tam Giang lagoon, Vietnam.

Tam Giang lagoon is the largest brackish water ecosystem in South-east Asia. It provides livelihoods for around 300,000 small scale fishers who depend totally or partly on lagoon fisheries resources. The high density of fishing gears, the diversity of lagoon uses and property rights have put this social - ecological system under threat. The social, economic and ecological challenges confronting the lagoon require a transformation of lagoon governance that can cope with the complexity of the system. Under these circumstances, co-management has been introduced progressively since 2009, with the aim of improving the sustainability of the lagoon system.

This research was conducted between late 2011 and early 2012 at six fishing communities in Tam Giang lagoon in which different forms of co-management have been arranged. Information was gathered from in-depth interviews with 25 people who were fishery managers, co-management experts and practitioners, staff of co-management donors and fishers. In addition 12 focus group discussions and a 252-sample survey with fishers were conducted.

This paper investigates the institutional arrangements created for co-management and how these interact with pre-existing government regulations; the incentives and motivations for fishers to participate in co-management; and policy implications for sustainable co-management.

The findings highlight the development of the Fisher's Organizations (Fishery Associations) at community level, each managing defined areas, with the district government. So far there are 64 Fishery Associations, but only about 33 per cent of the lagoon area has been allocated to Fishery Associations. The remainder is to be allocated progressively as more of the 64 Fishery Associations are considered ready for their role.

All participants identify the allocation of fishing rights (Territorial Use Rights for Fisheries) to Fishery Associations as the most significant aspect of the co-management initiatives, as this provides an incentive for fishers to participate in co-management. Other important factors that influencing fishers' participation in co-management are trust in Fishery Association leaders, the reputation and capacity of the leaders, and how the leaders act as role models.

As the initiative of co-management came originally from different international donor agencies, this has resulted in an uneven system in which different Fishery Associations participate on somewhat different terms, and government 'ownership' of the entire system is weak. The co-management system in Tam Giang lagoon also reveals potential failure if fisher's efforts do not receive timely support from local government, and national

government policy and legislation are inconsistent with the co-management system.

Keywords: Co-management, Sustainability, Fishing right

Oral presentation

Is co-management an option in Europe? Case study of the Asturian (N. Spain) gooseneck barnacle fishery.

Rivera A., García-Florez L., Gelcich S. and Acuña J.L.

There is an increasing interest on co-management as an alternative to the race for fish, yet most examples come from non-european countries. Since its inception and for the past 20 years, the gooseneck barnacle fishery in the Asturian coast (N Spain) has been managed by assigning Territorial User Rights for Fishing to each fishing guild. This arrangement allows the fishermen to participate actively in the management and data gathering processes. Currently, the system consists of seven management areas, each one some tens of kilometers long. The incorporation of Local Ecological Knowledge has led to within-area fragmentation of the management units down to single rocks as small as 10 m long, which are managed according to different protection levels. The detailed reports produced by the fishermen on landings and fishing effort for those small units represent an extraordinarily rich and detailed source of information. Due to declining trends in landings, in 2004 the individual daily catch was reduced from 8 to 6 kg per person and day in six of the management areas. Here we report that following this shift, the fishery showed clear signs of recovery, with increasing catches per unit effort in most of the management areas. The gooseneck barnacle TURF system in N Spain illustrates that adaptive co-management may lead to sustainable benthic fisheries in Europe.

Keywords: Co-management, LEK, TURFs, sustainability, *P. pollicipes*

Oral presentation

Identifying supportive governance structures for the enhancement of stewardship in Caribbean coral reef fisheries

Turner R.A., Forster J., Fitzsimmons C., Mahon R., Peterson A., Stead S.M.

Small-scale fisheries dominate fisheries activity in the Caribbean, and supporting these fisheries is one of many important ecosystem services that coral reefs provide to coastal communities. However, fishing livelihoods dependent on Caribbean coral reefs face an uncertain future with global climate change and mounting anthropogenic pressures threatening ecosystem integrity. In the context of future threats to coral reefs, improved governance is considered critical to enhance the efficacy of coral reef management. Increasing emphasis is placed on identifying governance arrangements that support resource user participation and engagement, and are expected to confer support for management and engender stewardship among fishers and other resource users.

Few studies examine perspectives of resource users in relation to the full spectrum of articulated principles for good governance processes, including participation and engagement. Studies linking resource user perceptions and structural arrangements at multiple sites and contexts are rare, and lack empirical support. In this study of Caribbean coral reef governance, we quantify perceptions of coral reef governance among reef fishers and other resource users in coral reef-dependent communities in relation to principles of 'good governance' in twelve communities across four Caribbean countries (Barbados, Belize, Honduras and St. Kitts and Nevis). In addition, we identify underlying themes driving differences in perceptions, and identify associated structural characteristics of governance arrangements.

The results illustrate that resource user perceptions of coral reef governance can be described using two underlying themes explaining over 50% of the variation in the data analysed. Based on these themes, three distinct clusters were identified reflecting different perceptions of reef governance among the communities studied, identifying strong differences by country, and linking perceptions with existing governance arrangements. Communities in which perceptions of governance process were most positive shared certain characteristics, including a strong NGO presence in the community, delegated management arrangements in which considerable decision-making occurred at a local level, active resource user organisations and access to information about coral reefs and their management.

This paper contributes to an improved understanding of how resource user perceptions relate to diverse governance arrangements in the Wider Caribbean Region. Commonalities in governance arrangements support arguments that certain structural characteristics of governance systems lead to improved governance outcomes. Small-scale fisheries governance may be more informed and effective if perceptions are used to identify areas in which to pursue greater engagement of resource users in stewardship.

Keywords: Coral reefs; Perceptions; Governance; Engagement; Caribbean

Oral presentation

Session D5: Tracking for Conservation

Oral Presentations

Friday 27 June, 10:30-12:00 Parallel session 8
Room D3

Time	Presenter	Title
10:30-10:45	Campagna, Claudio	Pelagic species and large spaces in the ocean: from sustainability to conservation
10:45-11:00	Fernandez Chacon, Albert	Modelling growth, dispersal and mortality of coastal Atlantic cod in Southern Norway: the effects of a recently established Marine Protected Area
11:00-11:15	Costa, Daniel	Habitat preference of crabeater seals in the rapidly changing western Antarctic Peninsula
11:15-11:30	Skerritt, Daniel	Investigating European lobster (<i>Homarus gammarus</i>) movement & habitat utilisation using acoustic telemetry
11:30-11:45	Stewart, Joshua	Tracking Giants: Tagging oceanic manta rays provides insights into their conservation
11:45-12:00	Vedor, Marisa	The European Silver Eel (<i>Anguilla anguilla</i>) Spawning migration: marathon or sprint?

Pelagic species and large spaces in the ocean: from sustainability to conservation

Campagna C. and Costa D.

The 1980s initiated the era of sustainable development and the 2000s that of the Anthropocene. During both periods, the leading perspective was that the world should be the way humans want and need it to be. Science is affected by these visions. While scientists are actively injecting new information and concepts into the structure of ecological knowledge, including threats to biodiversity and habitats, the gap between information available and conservation solution, including tools to implement conservation at scale, expands. For example, today the requirements for effective marine protected areas are well understood for the conditions of the ocean a decade ago. The gap is immense when considering policy in the context of the Law of the Sea. Marine science claims to have a conservation implication but, in practice, goals are rarely directly aimed at solving conservation issues; conservation ending being a collateral product of the marine scientific endeavor. Few species within marine diversity illustrate these gaps better than pelagic birds and mammals, animals that operate over the global ocean. While we understand that these species are distributed over millions of square kilometers, and that their protection requires movable, seasonal and/or transboundary protected areas, policy and governance scenarios are not aligned to work that way. Not even at the discourse level conservation efforts properly reflect the need to evolve and adapt to incorporate our greater understanding into conservation practice. Common to commercial fisheries and pelagic predators is that they both operate at large scales. But while fisheries have been developed within a framework that has gained global political support (sustainability), the conservation of top predators is most effective at the local level, independent of the need for global action. Aligning the priority of science with those of conservation may require adaptation, but to fulfill the need is of paramount importance if the Anthropocene is not to be the era that lasted the least.

Keywords: Anthropocene, conservation issues, pelagic predators

Oral presentation

Habitat preference of crabeater seals in the rapidly changing western Antarctic Peninsula

Hückstädt L.A., Palacios D.M., Piñones M.A., McDonald B.I., Dinniman M., Hofmann E.E., Burns J.M., Goebel M.E., Fedak M.A., Crocker D.E. and Costa D.P.

We created a suite of habitat models for a conspicuous predator of the western Antarctic Peninsula (wAP), the crabeater seal (*Lobodon carcinophaga*), a highly specialized predator of Antarctic krill (*Euphausia superba*), and likely the largest consumer of krill in the world. The characteristics of the species, such as its rather limited feeding niche, relatively low mobility, and high dependence on sea ice as substrate, make the crabeater seal in the wAP a species of high interest in studies of consequences of climate change, since it is likely that this species will be highly impacted by the drastic environmental changes predicted for the area. A total of 42 crabeater seals were tagged in 2001, 2002 and 2007, which transmitted data for 4 – 189 days. Mean transit rate for seals in this study was 1.8 ± 0.6 km h⁻¹, whereas mean total distance travelled was 2586.6 ± 1720.8 km. Crabeater seals dived to an average depth of 102.3 ± 94.0 m, reaching a maximum depth of 713 m, whereas the mean dive duration was 353.8 ± 195.3 sec, with the longest dive lasting for a little over half an hour (1890 sec, longest dive ever recorded). Crabeater seals from the wAP presented a coastal distribution, preferably occupying water of the inner continental shelf, and rarely venturing beyond the break of the continental shelf (1,000-m isobath). Most individuals' movements occurred between Anvers Island and Alexander Island, including Marguerite Bay, with few exceptions of animals heading north of this area to reach the area of the Bransfield Strait and the South Shetland Islands. We constructed 8 different habitat models using Non Parametric Multiplicative Regression. The best habitat model, as selected based on logB and AUC values included bathymetric and water column oceanographic features. Crabeater seals preferred shelf areas between 100 and 200 km from the shelf break, with bathymetric slope of about 5° (~10%), and shallow depths (<500 m deep). As well, we found a negative trend between crabeater seals presence and the maximum temperature below 100 m, suggesting that crabeater seals avoid zones of intrusions of warm, off-shelf Circumpolar Deep Water (CDW), as well as sea surface temperatures above the freezing point for sea water (> -0.5°C). Based on these results, we simulated the environmental conditions under climate change scenarios using a Regional Ocean Model Simulation (ROMS) model for the study area, allowing us to predict and evaluate the changes in patterns of habitat utilization of crabeater seals under such conditions in the wAP.

Keywords: Habitat, modeling, Antarctic Peninsula, climate change

Oral presentation

Modelling growth, dispersal and mortality of coastal Atlantic cod in Southern Norway: the effects of a recently established Marine Protected Area

Fernandez-Chacon A., Moland Olsen E., Moland E. and Espeland S.

Fisheries worldwide and the cod fishery in particular show increasing signs of overexploitation. Marine Protected Areas (MPAs) are widely seen as a useful management tool to restore fisheries, but to make sure their objectives are met, scientific assessments are required, especially at their early stages of implementation. Here we present the results of a 9-year (2005-2013) capture-recapture study aimed at coastal Atlantic cod in the Skagerrak area (South Norway), where a partially protected area was established in 2006 at one location. Mark-recapture techniques, by following individually marked animals over time, are useful monitoring tools, but due to the imperfect detection of individuals, cod tags used in this study included an economic reward in order to involve fishermen and to increase reporting rates. Data collected on both live recaptures and dead recoveries were analysed under a multistate modelling approach, an extension of the classical mark-recapture models that allows the incorporation of dynamic individual states such as geographic location or body size. Such models yielded reliable estimates of survival, growth, dispersal and proportions of deaths due to different causes of mortality, and allowed us to assess the influence of both extrinsic (MPA) and intrinsic (body size) factors on key vital rates. Model selection revealed differences in survival between protected and unprotected areas, with survival being on average 25% higher inside the MPA. No differences in growth rates were detected between locations and dispersal rates were on average low, though emigration from the MPA was higher than immigration into it. Reporting rates of dead fish increased with tag reward and compared to other fishing gear, hand line was an important mortality factor for smaller cod and the dominant cause of death within the MPA. Results show that partial protection has immediate positive effects on local survival and possibly on dispersal that may enhance metapopulation persistence at the regional level. Due to the high proportion of deaths caused by fishing activities, we predict the benefits of the recently established MPA could be even higher if it became a fully no-take reserve in the future.

Keywords: MPAs, Cod population dynamics, Multistate models

Oral presentation

Investigating European lobster (*Homarus gammarus*) movement and habitat utilisation using acoustic telemetry

Skerritt D.J., Fitzsimmons C. and Polunin N.V.C.

European lobster, *Homarus gammarus*, supports one of the most valuable UK fisheries, but stocks are considered to be fully exploited. The UK government proposes to implement a network of marine reserves around the UK, capable of protecting key habitats and rebuilding marine populations, particularly less mobile species or those with high site fidelity. Significant knowledge gaps exist regarding habitat-use and movements of *H. gammarus*. These directly influence our ability to determine distribution, or design effective reserves to protect stocks. Research is urgently required as inshore fishing fleets are increasingly reliant on the continued productivity of shellfish stocks in the light of reported failures of fin-fish stocks.

This paper presents results from a small-scale acoustic telemetry tracking study in 2013 that used V13 acoustic transmitters along with a network of 12 VR2W receivers, to monitor the movements of individuals within a 1.3*1.3km area of seafloor. This approach allows for fine-scale monitoring of large cohorts, with several positions gained every hour for each individual. 44 lobsters of varying size (65-98 mm carapace length) were tagged and positional data collected for 42 days during the summer (May-June) and 35 days during winter (Oct-Nov). Results of site fidelity, home-range size and habitat utilisation will be presented, analysed by sex, size, and season; information vital for the development of sound regional management plans and effective marine reserve design.

Summer data show all lobsters cluster along the edges of rocky reef habitat, with as many as six tagged lobsters within a 20 m radius; females had restricted home-ranges (20-40m diameter) around their central locations, and were less likely to move away from the hard substrate. Male lobster movement although clustered along the edge of the reef, was much more variable with a larger home-range (30-60 m) and greater amount of movement into surrounding soft substrate, males appear to have home-ranges centred around multiple locations, whereas females were less likely to change location, appearing more restricted by habitat than that of the freely moving males.

The technology has been little used in the UK, and this is the first such study in the country. As autonomous acoustic signals are employed, it offers an in situ insight into undisturbed behaviours and real-time movements of the cryptic lobster, that trapping or diving studies cannot replicate. The outcomes of the study will provide much needed information on *H. gammarus* behaviour, increasing understanding of the species, and aiding the assessment of the effectiveness of reserves for lobster stocks and the potential for spillover into the fishery.

Keywords: Acoustic-telemetry, movement, habitat, home-range, *Homarus gammarus*

Oral presentation

Tracking Giants: Tagging oceanic manta rays provides insights into their conservation

Stewart J., Beale C., Pilkington-Vincett R. and Semmens B,

Connectivity between subpopulations of wide-ranging marine megafauna has substantial implications for the susceptibility of these species to fisheries impacts and the development of practical, effective conservation and management strategies. We examine the geographic range and spatial dynamics of oceanic manta rays in the Raja Ampat marine region of Indonesia. Oceanic manta rays, a poorly understood, charismatic marine megafauna, are under intense fishing pressure worldwide. One of several species of Mobulid rays whose gill rakers are used as a pseudo-remedy in Traditional Chinese Medicine, thousands of mantas are killed each year in developing countries such as Sri Lanka and Indonesia. Given this intense harvest and the species' low reproductive rates, manta populations are in decline globally, threatening economically important ecotourism programs in many developing countries. Despite their popularity with the public, mantas are one of the few remaining marine megafauna whose spatial ecology has not been closely examined. By investigating the movements and spatial dynamics of oceanic mantas, we intend to highlight subpopulations with increased susceptibility to overfishing, develop regional conservation recommendations, and identify critical habitats that can be protected from an ecosystem management perspective.

Initial results from satellite telemetry suggest a high degree of site affinity to Raja Ampat, increasing the vulnerability of the local population—and the ecotourism revenue that it produces—to targeted fisheries. Tag data indicate that mantas did not exhibit migratory behaviour in response to a monsoonal shift or changes in primary productivity, nor did they associate with high primary productivity regions. A restricted geographic range suggests an isolated population that will decline quickly in response to targeted fisheries, and which will not benefit from population subsidies from regions with intact manta populations in the event of local extirpation. Mantas spent the majority of their time below 20 meters, suggesting that a non-pelagic resource may provide a year-round food source, explaining to some degree the observed site affinity. Furthermore, the diving behaviour exhibited by tagged mantas provides insight into their susceptibility to various fishing gear and techniques found in the region, such as gill nets and boat-based harpooning.

Keywords: Satellite Telemetry, Elasmobranch, Spatial Ecology, Conservation
Oral presentation

The European Silver Eel (*Anguilla anguilla*) Spawning migration: marathon or sprint?

Vedor M., Righton D., Silva T. and Metcalfe J.

The population and recruitment of European eels has declined dramatically over the last thirty years. Several anthropogenic threats to the eel population were identified and, in response, the EU established a management plan that imposes restrictions on exploitation. However, the impact of changes in oceanic and environmental factors may also affect the population dynamics of eels and it has been suggested that migration failure may have contributed to the collapse in eel recruitment.

We used data collected from electronic tagging experiments to map the behaviour and thermal experience of female silver eels as they migrated across the Atlantic Ocean. The eels travelled up to 50 km per day and exhibited a consistent vertical diel movement pattern, ascending to warmer shallower waters at dusk and descending into deep, colder water at dawn, from ~200–900m and 14–9°C every day. During the day and night the vertical movement was consistently distinct, suggesting foraging for cues, predator avoidance or metabolism regulation. Female silver eels migrate over 6000 km in 10 months up to the Azores. To assess energy use during the migration, I conducted respirometry experiments to determine metabolic rates at different temperatures, and extrapolated these to the recorded observations of thermal experience and swimming speed from the tagging data.

The results of this study provide the first estimates of migration routes and energy expenditure, as well diel vertical migration behaviour analysis of free-ranging eels during their oceanic migration shedding new light on the role of fat reserves during the spawning migration and the impact that trends in fat content may have on spawning success of the European eel. This application of experimental results to the eel migration success will help to establish how management measures and effective conservation plans might need to adapt in the future.

Keywords: Conservation, tag, physiology, oceanography, eel, spawn

Oral presentation

Session E1: Changing ecosystems in Subarctic and Arctic regions

Oral presentations

Tuesday 24 June, 11:00-12:30 Parallel session 1

Room D8

Time	Presenter	Title
11:00-11:10	Drinkwater, Ken	Introduction to ESSAS and E1
11:10-11:30	Neuer, Susanne	Export Variability of Algal Communities and Organic Matter from Land Fast Arctic Sea Ice
11:30-11:50	Dunton, Kenneth	The changing physical dynamics and biological seasonality of lagoon ecosystems along the eastern Alaska Beaufort Sea Coast: linkages to food webs and carbon resources
11:50-12:10	Chen, Jianfang	Deepening of Nutricline and Response of Biological Pump in the West Arctic Ocean after Summer Sea Ice Retreat
12:10-12:30	Matsuno, Kohei	Seasonal changes in zooplankton swimmer and faecal pellets collected by sediment trap in the western Arctic Ocean

Tuesday 24 June, 14:00-15:30 Parallel session 2

Room D8

Time	Presenter	Title
14:00-14:15	Mathis, Jeremy	Ocean Acidification in the Pacific-Arctic Region: Perceptions, Risks and Economics
14:15-14:30	Nishino, Shigeto	Shoaling of the nutricline with an increase in near-freezing temperature water in the Makarov Basin
14:30-14:45	Assmy, Philipp	Phytoplankton and ice-algal bloom dynamics in the Arctic Ocean north of Svalbard
14:45-15:00	Fujiwara, Amane	Relationship between bottom oxygen concentration and primary production at the Chukchi Sea biological hotspot
15:00-15:15	Degen, Renate	Patterns and trends of macrobenthic production from the Fram Strait to the Central Arctic
15:15-15:30	All	Discussion

Session E1: Subarctic and Arctic regions

Tuesday 24 June, 16:00-17:30 Parallel session 3

Room D8

Time	Presenter	Title
16:00-16:15	McBride, Margaret M.	Krill, Climate, and Contrasting Future Scenarios for Arctic and Antarctic Fisheries
16:15-16:30	Hunt, George	What controls the distribution and abundance of euphausiids over the southeastern Bering Sea shelf?
16:30-16:45	Søreide, Janne E.	Energetic costs for the Arctic copepod <i>Calanus glacialis</i> during overwintering
16:45-17:00	Stübner, Eike	Common strangers - year round study of meroplankton in Adventfjorden, Svalbard
17:00-17:15	Ray, Jessica Louise	Quantitative PCR and pyrosequencing of micro-eukaryote SSU amplicons reveal relative importance of <i>P. pouchetii</i> in diet of <i>Calanus</i> sp. (Maxillopoda:Calanoida) in coastal and pelagic ecosystems
17:15-17:30	All	Discussion

Wednesday 25 June, 11:00-12:30 Parallel session 4

Room D8

Time	Presenter	Title
11:00-11:15	Lien, Vidar S.	Variability of Atlantic Water flow towards the northern Barents Sea and its impact on winter sea ice cover
11:15-11:30	Drinkwater, Ken	Effects of Future Climate Change on the Marine Ecosystems of the Subarctic Seas
11:30-11:45	Mueter, Franz	Variability in the Subarctic to Arctic transition region and implications for fish populations in the Arctic Ocean
11:45-12:00	Popova, Ekaterina	Future of Arctic Ocean ecosystem and its climatic drivers
12:00-12:15	Sundby, Svein	Swordfish towards the Arctic Atlantic in Climate Change
12:15-12:30	Mueter, Franz	Summary of E1

Session E1: Subarctic and Arctic regions

Poster Presentations

Tuesday 24 June, Poster Session 1

ID	Presenter	Title
E1.P1	Varpe, Øystein	Breeding later at higher latitudes: explaining seabird phenology along a latitudinal gradient from the Norwegian to the Barents Sea
E1.P2	Ken Drinkwater	Paleoecology of Subarctic Seas: ESSAS Expansion into Long-Term Marine Ecodynamics and Human History
E1.P3	Iñiguez Moreno, Concepcion	Increased partial pressure of CO ₂ affects the carbon balance of two major Arctic brown seaweeds: <i>Desmarestia aculeata</i> and <i>Alaria esculenta</i>
E1.P4	Itoh, Fumihiro	Analysis of a Unique Adaptation Mechanism of Newly Established Arctic Strains of the Coccolithophore <i>Emiliana huxleyi</i> to low temperature
E1.P5	Onodera, Jonaotaro	Sinking particle flux of siliceous phytoplankton and the relationship with oceanographic variation in the southern Northwind Abyssal Plain
E1.P6	Thomas, Helmuth	Inorganic Carbon Cycling and the Biogeochemical Processes in Hudson Bay
E1.P7	Townhill, Bryony	Historical diets, food web dynamics and climate in the Arctic
E1.P8	Uchimiya, Mario	Atmospheric forcing resulted in enhanced microbial production in the water column of the Chukchi Shelf, western Arctic, in early autumn
E1.P9	Ji, Zhongqiang	Nutrient Characteristics in Arctic Kongsfjorden, Summer 2010

Phytoplankton and ice-algal bloom dynamics in the Arctic Ocean north of Svalbard

Assmy P., Hop H., Sundfjord A., Granskog M., Peeken I. and Lunau M.

The Arctic Ocean north of Svalbard is strongly influenced by advection of warm Atlantic water masses with the West Spitzbergen Current. The area is dominated by first year-ice and a large open water fraction already early in the growth season and might constitute a harbinger of future ecosystem changes in the Arctic Ocean at large. During the Centre for Ice, Climate and Ecosystems cruise with RV Lance in spring 2011 we studied the phytoplankton and ice-algal bloom dynamics over the shelf break north of Svalbard. Due to the large open water fraction, the phytoplankton spring bloom commenced already at the end of April and showed a similar timing to blooms along the coast of northern Norway. Centric chain-forming diatoms of the genera *Thalassiosira* spp. and *Chaetoceros* spp. dominated bloom biomass because they maintained high growth rates and suffered low mortality by zooplankton grazing during the early stages of the bloom. Ice-algal standing stocks on the other hand were comparably low likely because basal ice melting induced by heat dissipation from warm Atlantic water masses limited biomass build-up. Species composition of ice-algal communities differed significantly from that of phytoplankton communities casting doubt on the role of ice algae for the seeding of the pelagic bloom.

Keywords: Svalbard, spring bloom, diatoms, ice algae

Oral presentation

Deepening of Nutricline and Response of Biological Pump in the West Arctic Ocean after Summer Sea Ice Retreat

Chen J., Jin, H., Li H., Zhuang, Y. and Gao S.

With decreasing of ice cover there is the potential for deepening of nutricline and an increasing of biological pump in the Arctic Ocean because of more nutrients in the euphotic zone will be consumed in an ice free sea or open ocean. Since 1999 (in summers, 1999, 2003, 2008, 2010 and 2012), five Chinese Icebreaker Xuelong Arctic Expeditions has been carried out in Chukchi Sea and Canadian Basin where upper ocean nutrients are abundant compared with European sector of the Arctic Ocean. During those cruises, we analyzed nutrients, DO, pH, Chl α , opal and HPLC pigments in the water column as well as biomarkers in a 3.6m sedimentary core in order to check how biological pump structure changes with decreasing of sea ice. The results showed that size fractionation of Chl α and opal, Chl α -maximum depth, phytoplankton communities changed dramatically along the longitudinal 170°W section (from open water to sea ice cover) since 1999. A highlight of those changes is deepening of nutricline in summer and slight increasing of nano or pico phytoplankton groups in the Chukchi Sea since 1999. Sedimentary biomarkers indicated that relative abundance of diatoms increased and the contributions of haptophytes decreased since last 250a.

Keywords: Nutricline, Biological Pump, Arctic Ocean

Oral presentation

Patterns and trends of macrobenthic production from the Fram Strait to the Central Arctic

Degen R., Vedenin A., Gusky M., Boetius A. and Brey, T.

With the Arctic Ocean shifting towards a system with a seasonal ice cover solely, Arctic marine ecosystems are facing new challenges. Deep-sea macrobenthic communities are ideal integrators of the upcoming changes as they rely in their nutrition almost entirely on the input from upper layers and hence mirror changes of surface production in their own dynamics. But as benthic studies of the deep Arctic Ocean are scarce we are lacking reliable baseline information on the “pre-change” system state. To overcome this obstacle we combined legacy data from the past 20 years, as well as recent field studies in our approach. We investigated the relationship of standing stock, productivity (P/B) and secondary production (P) of macrobenthos with water depth, geographical latitude and sea ice concentration along a transect from Fram Strait up to the high Arctic basins. Community P/B and P were estimated using the multi-parameter ANN model developed by Brey (2012). Our results confirm the previously described negative relationship of water depth and macrofauna standing stock in the Arctic deep-sea (Bluhm et al. 2011). Furthermore we could show that increasing sea-ice concentration and latitude correlated with decreasing standing stock and P of $< 75 \text{ mg C m}^{-2} \text{ y}^{-1}$. Stations under influence of the marginal ice zone (MIZ) showed much higher standing stock and P (means between 400-1400 $\text{mg C m}^{-2} \text{ y}^{-1}$) - even at depths up to 3700 m. We conclude that particle flux is the key factor structuring benthic communities in the deep Arctic Ocean, explaining both the low values in the ice-covered basins and the high values found along the MIZ. With the ongoing trend of a northward migrating seasonal ice zone carbon fluxes will shift accordingly and Arctic areas that are fueled by high primary production now may experience strong decline in the future. More northern and currently food limited areas on the other hand will probably benefit from the new situation, as deep-sea communities can react very fast on new food input and would so potentially form new hotspots of benthic secondary production.

Keywords: Arctic, deep-sea, macrobenthos, production, carbon flux

Oral presentation

Effects of Future Climate Change on the Marine Ecosystems of the Subarctic Seas

Drinkwater K.

From its inception, one of the main objectives the Ecosystem Studies of Sub-Arctic Seas (ESSAS) programme has been to determine the response of these seas to future climate change. From the work of ESSAS and others, this Oral presents the likely atmospheric as well as physical and chemical oceanographic changes that may occur in the future in both the North Atlantic and North Pacific oceans. The ecosystems responses to these changes will then be discussed, with particular focus on the phytoplankton, zooplankton and fish resources. This will include changes in abundance, production and distribution. As well, species interactions through predator-prey and competition linkages will be mentioned. The mechanisms through which the climate affects the various ecosystem components will be highlighted, where known. In addition, the implications on fisheries will be briefly discussed. Comparisons between the different ocean basins and seas within these basins will be made to determine which ecological responses are fundamental and which ones might be unique to a particular ecosystem or type of ecosystem. Mention will be made of the knowledge gaps that need to be filled in order to improve our future ecosystem projections and some recommendations for future research.

Keywords: Subarctic, climate change, ecosystems, fish resources

Oral presentation

Paleoecology of Subarctic Seas: ESSAS Expansion into Long-Term Marine Ecodynamics and Human History

Fitzhugh B., [Drinkwater K.](#) and and the PESAS Working Group (ESSAS)

The "Paleoecology of Subarctic Seas" (PESAS) is a new ESSAS working group assembled for the first time at the ESSAS Open Science meeting in Copenhagen in April 2014. This group adds a deep temporal perspective to the marine ecological approach of ESSAS to synthesize available evidence on past climate, physical oceanography, marine ecology, and human adaptations in the northern subarctic seas. Taking the North Pacific and North Atlantic basins in comparative terms, this group is looking at how deglaciation and Holocene climate change affected currents, biological productivity, and species distributions in the subarctic ecosystems and how these conditioned human maritime lifeways and economies. Through a broadly synthetic and comparative approach this group hopes to better understand the relationship between key physical, biological and social ecosystem parameters and to better understand how humans have become tied to and increasingly altered these ecosystems throughout the Holocene to recent centuries. Participants include leaders in paleoclimatology, paleoceanography/marine paleoecology, zooarchaeology, archaeology and history. This Oral will report on the early stages of this effort and the key research questions emerged from the ESSAS open meeting to frame the endeavor.

Keywords: paleoclimatology, paleoceanography, paleoecology, zooarchaeology, archaeology, history

Poster presentation

The changing physical dynamics and biological seasonality of lagoon ecosystems along the eastern Alaska Beaufort Sea Coast: linkages to food webs and carbon resources

Dunton K., McClelland J.W., Connelly T.L., Crump B.C., Kellogg C.T. E., Liu Z. and McTigue N.

Coastal lagoons of the eastern Beaufort Sea are extraordinarily diverse with respect to their physical and biological characteristics and serve as critical habitat for an array of organisms of enormous ecological and subsistence value. Their unique physiography, a product of physical processes driven by ice, sediment transport, and freshwater inflows is linked to their importance as nurseries for an array of fauna and feeding grounds for over 150 species of migratory birds. Our work has revealed that these lagoons are subject to substantial seasonal variations in their hydrography, largely driven by the magnitude of water exchange processes with the Beaufort Sea, especially during the ice-covered period. Distinct vertical stratification in winter, likely a product of limited circulation and high water residence times, results in hypersaline (43) lagoon waters and net heterotrophic (values to 25% oxygen saturation) during winter, before rebounding during the period of ice break-up to net autotrophic (>100% saturation). In concert with these observed physical events, we find distinct seasonal patterns in microbial community structure, contributions of terrestrial and marine-sourced particulate organic matter (POM), and levels of inorganic-N. DOM concentrations and C:N ratios are highest in association with terrestrial runoff in the spring. Our visits to study sites along the eastern Alaskan Beaufort Sea coast during both ice-covered and open-water periods reveal high concentrations of sediment chlorophyll in late winter and early spring, nearly twice that measured during the summer months. HPLC analyses revealed a high proportion of diatom pigments (fucoxanthin). Stable isotopic analyses of infauna and epifaunal species have confirmed the significant assimilation of marine carbon during the period of ice-cover, with increasing dependence on terrestrial organic matter through the summer, contrary to our original hypotheses on the seasonal importance of autochthonous vs. allochthonous carbon sources to lagoon food webs. We also found that fatty acid markers to confirm that variations in ^{13}C are indeed coupled with variations in terrestrial contributions. Measurements of water and sediment chemistry, benthic and water column community characteristics, and natural abundance isotopic tracers promise to reveal the dynamic nature of these productive lagoon ecosystems under different hydrologic conditions. Our research has benefited from the special relationships we have developed with the Inupiat community of Kaktovik through our field K-12 educational programs and partnerships with local citizens.

Keywords: food webs, terrestrial , marine, arctic

Oral presentation

Relationship between bottom oxygen concentration and primary production at the Chukchi Sea biological hotspot

Fujiwara A., Hirawake T., Nishino S., Kikuchi T. and Saitoh, S.-I.

The continental shelf region spread in the southern Chukchi Sea is one of the most biologically productive oceans, so called “biological hotspot” (CHS). Dissolved oxygen (DO) decreases at bottom of the hotspot due to the large sediment community oxygen consumption through remineralization of organic matter produced at the upper layer by phytoplankton (primary production, PP). Therefore, we hypothesized that temporally integrated primary production negatively influences on the variability of bottom DO at the CHS. We aimed to clarify the relationship between temporal and spatial distribution of PP and CHS bottom DO.

In situ bottom DO at the CHS were measured during seven cruises conducted during late summers of 2002, 2004, 2006, 2008, 2010, 2012 and 2013. Satellite ocean color dataset, SeaWiFS and MODIS-Aqua, was used to calculate temporally integrated water column primary production (TPP) from the date became open water to date sampled for each year. Phytoplankton community size structure (FL) that defined as the ratio of algal biomass attributed to cells larger than 5 μm to the total was also estimated. SSMI-DMSP sea ice concentration data were used to calculate the distribution of the length of ice-free periods for each year. We investigated the relationship between inter-annual variability of bottom DO at CHS and spatial distribution of TPP. We also assessed how annual mean FL and length of ice-free days contribute to annual net primary production (APP).

Large inter-annual variability was found in both CHS bottom DO and TPP, though there is no statistically significant relationship between the two variables. It suggests that water column PP at CHS is not important to determine the bottom DO. On the other hand, statistically significant relationship between CHS bottom DO and TPP was found around the western side of Bering Strait, where extremely high APP and its large variability were observed. Our results suggest that horizontal advection of organic carbon from upstream more productive region (i.e. Bering Strait) is important to determine the CHS bottom DO, and high APP in the region probably cause low bottom DO during late summer at CHS. Next, we investigated the control factors of APP. Generally, the length of ice-free periods positively contributes to APP in the high latitude Arctic (Arrigo et al., 2011). In addition to their finding, we found annual mean phytoplankton size structure also co-varied with APP at the southern Chukchi Sea and Bering Strait region. That is to say, not only the length of growth season but also phytoplankton community structure is likely an important factor to determine APP around CHS. Continuous monitoring of PP and phytoplankton community structure is needed to clarify the mechanism of inter-annual variability of APP. It will contribute to comprehend the biogeochemical cycles and energy transport to higher trophic levels at CHS.

Keywords: Chukchi Sea, hotspot, primary production, DO

Oral presentation

What controls the distribution and abundance of euphausiids over the southeastern Bering Sea shelf?

Hunt G.L. Jr., Aydin K., De Robertis A., Ressler P., Gibson G., Pinchuk, A. and Williams B.

Euphausiids (*Thysanoessa* spp.) are a major component of the crustacean zooplankton biomass over the southeastern Bering Sea shelf, and are an important trophic link between primary producers and large marine predators, such as seabirds, great whales, and walleye pollock (*Gadus chalcogrammus*), with pollock accounting for 37% of predation on euphausiids. This high proportion of euphausiid consumption by pollock spurred interest in whether the distribution and biomass of euphausiids are controlled by pollock. Early work focused on a negative relationship over six years between pollock biomass and euphausiid biomass, which supports the idea of top-down control. However, when temperature and spatial location were also included in the analysis, temperature was found to be a better predictor of euphausiid abundance and distribution than pollock biomass, thus supporting bottom-up control through environmental effects correlated with temperature, possibly through effects on the production of euphausiid food. Estimates of summertime euphausiid biomass and productivity are highly uncertain, but comparisons of modeled pollock consumption and euphausiid production rates between 2004 and 2010 suggest that 6-15% of euphausiid production is consumed by pollock. Thus, these results support bottom-up control of euphausiids. However, during the study period (2004-2010), age-3+ pollock biomass averaged 7.1×10^6 metric tons (range 4.6 to 11.4×10^6 tons) compared to a high of in 1987 of 12.1×10^6 metric tons. We caution that, in times when pollock are more abundant, they in combination with the impact of other predators may exert top-down control on euphausiids.

Keywords: climate impacts, trophodynamics, walleye pollock

Oral presentation

Increased partial pressure of CO₂ affects the carbon balance of two major Arctic brown seaweeds: *Desmarestia aculeata* and *Alaria esculenta*

Iñiguez C., Carmona R., Lorenzo M.R. and Gordillo F.J.L.

Despite the high research interest on Arctic ecosystems due to its prime affection by Global Change, little is known about the consequences of elevated CO₂ on the C fluxes in seaweeds. These organisms commonly dominate the coastal systems, but there is a lack of knowledge on the cellular C balance and the competitive advantages and disadvantages triggered by increasing CO₂ levels. The physiological acclimation to an increased partial pressure of CO₂ of two ecologically relevant species of seaweeds (*Desmarestia aculeata* and *Alaria esculenta*) was analysed under laboratory conditions in the Kongsfjord (79 °N, 11°E; Spitsbergen, Norway). The biomass was collected by scuba divers at 5 m (*D. aculeata*) and 10 m (*A. esculenta*) depth in Hansneset bay. Algae were incubated for 7 days at two different CO₂ concentrations, 450 ppmV and 1300 ppmV, by bubbling the medium with normal air or CO₂ enriched air (hereafter LC and HC, respectively). The experiments were carried out in a controlled temperature room at 4 °C, an irradiance of 35 μmol m⁻² s⁻¹ and a photoperiod of 20:4 h (light:darkness). At the end of the incubation period relevant physiological and cellular variables were analysed: growth rate, net photosynthesis (by O₂ evolution and ¹⁴C fixation) and respiration, rapid light curves by PAM fluorometry, dissolved organic carbon (DOC) release, C:N ratio and stable carbon isotope discrimination (δ¹³C).

Our results showed an opposite behaviour for both species under increased dissolved CO₂. The growth rate of *D. aculeata* was negatively affected by HC while *A. esculenta* was positively affected. *Desmarestia aculeata* had a lower net photosynthesis rate and a higher respiration rate in HC, while *A. esculenta* presented no differences in net photosynthesis but a lower respiration rate in HC, respect to LC. Rapid light curves support these findings, indicating a lower maximum electron transport rate (ETR_{max}) at HC in *D. aculeata*, and a higher photosynthetic efficiency (α) and ETR_{max} at HC in *A. esculenta*. HC affected the nitrogen metabolism of these species in a different way, decreasing % N in *D. aculeata* and increasing it in *A. esculenta*. δ¹³C values indicate a deactivation of carbon concentration mechanisms (CCMs) at HC in both species, although in *A. esculenta* the differences were stronger than in *D. aculeata*. Also, the percentage of assimilated carbon being released was higher in HC for both species. The photosynthetic quotient (PQ) obtained for *A. esculenta* was in agreement with the δ¹³C values, showing a significant lower value for HC, which indicates a decrease in the energy expended in other processes different from C fixation like CCMs, and so, in this way the energy saved could be used for extra growth, increasing growth rate.

As concluding remarks, our results suggest that diversity of primary producers from Arctic coastal systems would be affected by increased dissolved CO₂ in seawater, favouring the spreading of some species in detriment of others, presumably with cascading effects, affecting the whole food web.

Keywords: CO₂, growth, photosynthesis, macroalgae

Poster presentation

Analysis of a Unique Adaptation Mechanism of Newly Established Arctic Strains of the Coccolithophore *Emiliana huxleyi* to low temperature

Itoh F., Satoh M., Harada N., Suzuki I. and Shiraiwa Y.

The coccolithophore *Emiliana huxleyi* which distributes widely from subtropical to high latitude oceans is known to be the most abundant bloom-forming unicellular calcifying alga. According to genome analysis, there are wide variations of genomes among strains isolated from various kinds of environments and regions (Read et al. 2013). We succeeded to isolate new strains from the Arctic Sea, MR67N (Lat. 67°30'N.) in 2010 and therefore intended to analyze their physiological properties whether the Arctic strains are different from others, or not, and how the Arctic strains are resistant to coldness.

In addition to the Arctic strain MR67N, *E. huxleyi* NIE 837 isolated from the Great Barrier Reef (actual collection site not available) was used as a reference strain. We cultured both strains at 20°C and 10°C. The cells of MR67N strain could acclimate to the low temperature within ca. 3 d and then proliferate at similar growth rate as at 20°C, whilst the cells of NIES 837 strain was markedly damaged and completely failed to grow at 10°C in further cultivation. However, NIES837 could grow at 15°C after acclimation at 10°C for 3 d, indicating that the low temperature conditions were not lethal to the cells at least for 3 d.

When the MR67N strain was transferred from 20°C to 10°C during growth, the activity of non-photochemical quenching (NPQ) and photosystem (PS) II, determined by chlorophyll fluorescence method, did not change significantly. We assumed that alternative excess energy dissipation pathway was activated except for xanthophyll cycle.

Therefore, we tried to determine the PTOX activity with the administration of propyl gallate, a specific inhibitor for PTOX (Josse et al., 2003), and found that PTOX activity was strongly induced at 10°C.

We further determined PTOX activity in high-light acclimated cells grown at 1000 $\mu\text{mol m}^{-2} \text{s}^{-1}$. However, PTOX activity was not induced by the high light. As previous report suggested that PTOX activity was induced under nutrients (e.g., nitrogen, phosphate, and iron) deficient conditions in diatom (McDonald et al., 2011), we tested whether nutrient deficiency induces PTOX activity or not. Under nitrate- or iron-deficient conditions, chlorophyll content of the cell and growth was greatly decreased. In the phosphorus deficiency, growth of the cell was suppressed although no chlorophyll content was altered. As far as we tested, PTOX activity was not induced by any nutrients deficient conditions, suggesting that PTOX is an important factor for the adaptation to low temperature, but not to high-light and nutrient deficiencies.

This study clearly presents that the Arctic strains of *E. huxleyi* possesses unique ability to acclimate/adapt to coldness by inducing PTOX activity which is specific to function only under low temperature, but not under high-light stress and nutrient deficiency.

McDonald et al. (2011). *Biochimica et Biophysica Acta* 1807: 954-967.

Josse et al. (2003). *Eur. J. Biochem* 270: 3787-3794.

Read B et al. (2013). *Nature* 499: 209-213.

Keywords: Arctic, coccolithophore, photosynthesis

Poster presentation

Nutrient Characteristics in Arctic Kongsfjorden, Summer 2010

Ji Z., Gao S., Jin H., He J., Bai Y., Wang B., Yang Z., Chen J.

Kongsfjorden is a glacial fjord in the Arctic (Svalbard). Atlantic and Arctic water outside fjord will exchange with water in the fjord through the glacier tunnel in the boundary between fjord and shelf; the glacial and terrestrial inputs will also have an effect on the water constitute, thus, changing the nutrients characteristics, and affecting the primary production in the fjord. In order to find out the nutrient characteristics and the limitation factors of the primary production, seawater and land water of the Kongsfjorden were sampled for nutrients and Chl a analyses, and an in-situ enrichment experiment was designed in summer 2010. According to the salinity and temperature of the water in summer 2010, it was found that the water in the fjord was less affected by the Atlantic water, and the Local water was the water mass in control. Besides, the surface water was characterized as high temperature and low salinity, strongly influenced by terrestrial inputs. The distribution of water masses and their sources decided the nutrients characteristics. The nutrients concentration in surface water was low, which met with the high Chlorophyll a concentration, indicating the consumption of nutrients by phytoplankton. And the glacier water also diluted the surface water. Moreover, the N/P and N/Si ratios in the surface water indicated that nitrogen nutrient was the main nutrients component limiting the growth of phytoplankton in the fjord, and the in-situ nutrients enrichment experiment proved this. The zooplankton metabolism was the main contributor for the high NH₄-N and NO₂-N concentrations at 100m water depth, suggesting the zooplankton feeding might reduce the primary production. Nutrients enhancement of the local water to the residual water of last autumn and winter, was mostly induced by nutrients regeneration from the particulates in the water.

Keywords: Kongsfjorden, Nutrients, Water mass, limitation factor

Poster presentation

Variability of Atlantic Water flow towards the northern Barents Sea and its impact on winter sea ice cover

Lien V.S., Skagseth Ø., Vikebø F.B., Ådlandsvik B. and Ingvaldsen R.B.

During the last few decades, the Arctic has experienced large climatic changes, reflected in its shrinking ice cover. The two-branched inflow of warm and saline Atlantic Water to the Arctic is the major contributor of oceanic heat to the Arctic climate system. However, while the Atlantic Water entering the Arctic through the Fram Strait retains a large part of its heat as it flows along the Arctic continental slope, the branch flowing through the shallow Barents Sea loses a substantial amount of heat. This heat is either lost directly to the atmosphere or it contributes to the melting of sea ice. Events where the relative strengths of the two branches are affected by wind-induced Ekman transport off the northern Barents Sea shelf have recently been identified. Such events are mainly occurring during winter, and are manifested by anomalous transport of warm and saline Atlantic Water along the Polar Front towards the northern and central Barents Sea. Thus, the excess oceanic heat is readily available for melting sea ice. While the general reduction in Arctic sea ice cover has mainly occurred in summer, the largest variability in Arctic winter sea ice cover is found in the Barents Sea. Here, we present results on the relationship between heat transport anomalies and variations in the Barents Sea ice cover in winter. Furthermore, possible ecosystem impacts, such as changing habitats due to lateral movement of the marginal ice zone, are discussed.

Keywords: Atlantic Water; climate variability; Polar Front

Oral presentation

Ocean Acidification in the Pacific-Arctic Region: Perceptions, Risks and Economics

Mathis, J.T.

The extremely valuable commercial and subsistence fisheries of the Pacific-Arctic region are located in seas projected to experience rapid transitions in pH and other chemical parameters caused by ocean acidification (OA) in the coming decades. Many of the marine organisms that are most intensely affected by OA, such as mollusks contribute substantially to the region's commercial activities as well as the gross domestic product (GDP) of the United States as well as other countries. Prior studies of OA's potential impacts on human communities have focused on possible economic losses from specific scenarios of human dependence on harvests and damages to marine species. However, non-economic impacts due to OA are likely to also manifest, such as changes in food security or shifts in livelihoods. Here, we describe the current patterns of dependence on marine resources within the region that could be negatively impacted by OA and current community characteristics to determine the risk to the region's fishery sector. Results suggest that OA merits consideration in policy and adaptation planning, as it may represent yet another challenge to many communities that are already in socioeconomic decline. To determine the public awareness and understanding of this potentially game-changing threat we conducted a regional survey to better understand the multitude of variables that influence the perceptions of the risk associated with OA, as well as environmental literacy and support for mitigation efforts. This has helped us identify where there are gaps in understanding of OA and how future OA initiatives can be implemented in order to prepare individuals, communities, and the fishing industry for future changes in ocean chemistry.

Keywords: Ocean Acidification, High Latitude, Risks

Oral presentation

Seasonal changes in zooplankton swimmer and faecal pellets collected by sediment trap in the western Arctic Ocean

Matsuno K., Yamaguchi A., Fujiwara A., Onodera J., Watanabe E., Harada N. and Kikuchi T.

Most of the studies on zooplankton community in the Arctic Ocean have been made by net-collected samples. However, seasonal sea ice coverage in this area prevents accurate evaluation of their seasonal changes. To overcome these problems, analysis on zooplankton swimmers collected by sediment trap is a powerful tool. In the present study, we analyzed seasonal changes in zooplankton swimmers and faecal pellets collected by sediment trap moored at Northwind Abyssal Plain in the western Arctic Ocean.

Samples were collected by sediment trap moored at 184–260 m at St. NAPt (75°00′N, 162°00′W, bottom depth 1975 m) at 10–15 day intervals during 4 October 2010 to 18 September 2012. After the trap was retrieved, the total of 52 samples were gently sieved with 1 mm mesh, and the fine size fraction (< 1 mm) of each sample was filtered with membrane filter and weighed, then the total mass flux ($\text{mg DM m}^{-2} \text{ day}^{-1}$) was evaluated. For the aliquot of the fine size fraction, faecal pellets of zooplankton were counted with four morphological types (oval shape, cylinder shape, spherical shape and brown oval shape). Based on both size fraction samples (< 1 mm and \geq 1 mm), species identification and enumeration of zooplankton were made under a dissecting microscope. Based on zooplankton flux ($\text{ind. m}^{-2} \text{ day}^{-1}$), cluster analysis was made. To identify the species most responsible for the similarity between zooplankton communities, tests by SIMPER analysis were performed based on the flux.

Satellite data evaluated that the sea ice coverage period (November–June), open water period (August–October), and high chlorophyll a period (August–October). Total mass flux was ranged 0.1–263.3 $\text{mg DM m}^{-2} \text{ day}^{-1}$, and their peaks were at November when the onset of sea ice coverage. Within the faecal pellets, oval shape and spherical shape were dominated, and composed with 60% and 30%, respectively. As special characteristics of faecal pellets, brown oval shape was occurred only in open water period (July–August) and their maximum composition reached 80%. Zooplankton flux ranged 35–739 $\text{ind. m}^{-2} \text{ day}^{-1}$, and was significantly higher during September–November. Poecilostomatoid copepods were the most dominant taxa (annual mean \pm 1sd: 69 \pm 18%). As seasonal dominant taxa, bivalve larvae were marked during October–November (53%), and barnacle larvae were abundant in August 2011 (33%) but were not occurred in 2012. Based on the zooplankton flux, cluster analysis identified five zooplankton community groups. The occurrence of each group showed clear seasonality, and their changing timings were corresponded with the timing of onset or offset of ice coverage or seasonal changes in daylight hours.

Based on on-board experiments, the brown-oval-shape faecal pellets were thought to be egested by amphipods. The high brown-oval-shape faecal pellets during open water period may be the reflection of massive feeding activity of amphipods. For zooplankton swimmer, seasonal abundant bivalve and barnacle larvae are considered to be transported from shallower region. The annual change in occurrence of barnacle larvae (present in 2011 while not in 2012) would be caused by the annual changes in water mass formation at upper layer of St. NAPt.

Keywords: Arctic Ocean, sediment trap, zooplankton community

Oral presentation

Krill, Climate, and Contrasting Future Scenarios for Arctic and Antarctic Fisheries

McBride M.M., Dalpadado DP., Drinkwater K., Rune Godø O.R., Hobday A.J., Hollowed A.B., Kristiansen T., Murphy E.J., Ressler P.H., Subbey S., Hofmann E.E. and Loeng L.

Arctic and Antarctic marine systems have in common high latitudes, large seasonal changes in light levels, cold air and sea temperatures, and sea ice. In other ways, however, they are strikingly different, including their: age, extent, geological structure, ice stability, and food web structure. Both regions contain very rapidly warming areas and climate impacts have already been reported, as have dramatic future projections. However, the combined effects of a changing climate on oceanographic processes and food web dynamics are likely to influence their future fisheries in very different ways. Differences in the life-history strategies of the key zooplankton species (Antarctic krill in the Southern Ocean and *Calanus* copepods in the Arctic) will likely affect future productivity of fishery species and fisheries. To explore future scenarios for each region, this paper: 1) considers differing characteristics (including geographic, physical, and biological) that define polar marine ecosystems, and reviews known and projected impacts of climate change on key zooplankton species that may impact fished species; 2) summarizes existing fishery resources; 3) synthesizes this information to generate future scenarios for fisheries; and 4) considers the implications for future fisheries management. Published studies suggest that if an increase in open water during summer in Arctic and Sub-arctic Seas results in increased primary and secondary production, biomass may increase for some important commercial fish stocks and new mixes of species may become targeted. In contrast, published studies suggest that in the Southern Ocean the potential for existing species to adapt is mixed, and that the potential for invasion of large and highly productive pelagic finfish species appears to be low. Thus, future Southern Ocean fisheries may largely be dependent on existing species. It is clear from this review that new management approaches will be needed that account for the changing dynamics in these regions under climate change.

Keywords: Polar Regions, climate, zooplankton, foodwebs, fisheries

Oral presentation

Variability in the Subarctic to Arctic transition region and implications for fish populations in the Arctic Ocean

Mueter F.J., Gjøsæter H., Danielson S. and Drinkwater K.

Warmer waters, reduced seasonal ice cover and changes in ocean circulation affect the distribution of fish in the major subarctic seas with a potential for populations expanding into the Arctic Ocean. A strong gradient in species composition from warmer, subarctic waters to colder, Arctic waters implies a high potential for species expanding into Arctic waters as temperatures increase. The rate of expansion and the mechanisms by which species expand into the Arctic are likely to differ between the Pacific and Atlantic Arctic Gateways. Here we review the main pathways connecting the subarctic seas to the Arctic Ocean along these gateways, the main drivers affecting connectivity and fluxes through these gateways, and the evidence for changes in these fluxes and in the distribution and abundance of subarctic and arctic fish species. In the Pacific, we find little evidence to date for changes in the demersal fish community north of Bering Strait since the early 1990s and argue that such changes are unlikely to occur in the foreseeable future because (1) bottom temperatures on the shallow shelf are "reset" each winter, severely limiting the distribution of boreal fish species, and (2) there is no evidence that the inflow of warmer Pacific waters and associated fauna into the Chukchi Sea has increased as a result of large-scale warming. However, there is a potential for pelagic species to exploit the longer ice-free season and warmer water temperatures by expanding their summer feeding range into the Arctic, but evidence for either range expansions or increased abundances in the Pacific Arctic is limited. In contrast, increased inflows of warm Atlantic water into the Barents Sea and reductions in sea ice cover have resulted in the expansion of both demersal and pelagic species along the Atlantic Arctic Gateway and several commercially exploited stocks have recently increased to record high biomass levels.

Keywords: Advection, Arctic Gateway, fish distribution, warming

Oral presentation

Export variability of algal communities and organic matter from land fast Arctic sea ice

Neuer, S., Klinzler, K., Aumack, C. and Juhl, A.

In the early spring, sea ice algal communities within the sea ice dominate primary production of the Arctic Ocean. As the sea ice bloom terminates, algae are released into the nutrient rich waters, seeding blooms and feeding higher trophic levels both in the water column and the benthos. In situ measurements, settling experiments, and direct observations demonstrate that the algae are often lost from the ice in dramatic export events, lasting as little as a few days. The algae slough off the ice as individual particles and aggregates ranging widely in size. We investigated the development of the sea ice community including export events in a gradient of light levels dictated by the thickness of snow cover. Samples were obtained over three consecutive field seasons (2011-2013) during the spring bloom allowing us to investigate both seasonal as well as interannual variability. We observed an overall earlier ice algae export in 2012, which was characterized by a historically low sea ice extent in the Arctic, compared to 2013. Within each year, we observed a delay in export events from areas covered by thicker snow compared to areas covered by thinner snow, leading to a prolonged supply of organic matter to the underlying water column. Also, settling experiments carried out on melted sections of the recovered ice cores indicate a spatial and temporal change in particle size and sinking velocity based on both overlying snow depth and depth in the ice.

In addition to the algal export out of the ice, we found substantial organic matter pools retained within the ice after algae export events. A large fraction of the organic material retained within the lower portions of the ice may be comprised of exopolymers originally secreted by the sea ice algae. In contrast, organic matter retained in the upper layers of the ice may primarily be allochthonous in origin. Thus, as ice melts in spring, we show a predictable progression of organic matter fluxes out of the ice: ice algae themselves first, followed by ice algae exudates, then by older, allochthonous material. These pulses likely deliver organic matter of differing food quality to the Arctic marine food web with implications for the carbon cycle of the Arctic shelf ecosystem.

Keywords: sea ice, algae, snow depth, export

Oral presentation

Shoaling of the nutricline with an increase in near-freezing temperature water in the Makarov Basin

Nishino S., Itoh M., Williams W.J. and Semiletov I.

The water mass changes in the Makarov Basin and adjacent areas associated with the recent loss of Arctic sea ice had not been studied in detail. We combined data obtained from multiple cruises in these regions and used chemical tracers to investigate the spatial and temporal changes in water masses. Our data show that a previously present temperature maximum water has disappeared from the Makarov Basin and Chukchi Abyssal Plain due to enhanced cooling and convection in the East Siberian Sea. In addition, a large volume of water has formed by cooling and convection and is flowing into the Makarov Basin, producing a temperature minimum with relatively high nutrients and resulting in a shoaling of the nutricline. This temperature minimum water likely originated from the eastern part of the East Siberian Sea, where significant open water areas appeared after 2005 in the freeze-up season. The water mass boundary between this temperature minimum water and the Pacific-origin temperature minimum water shifted westward from the Chukchi Plateau in the early 2000s to the Mendeleev Ridge in the late 2000s, probably owing to a westward flow of the enhanced Beaufort Gyre associated with recent sea ice loss in the Canada Basin. Although the shoaling of the nutricline in the Makarov Basin could increase phytoplankton production, such production could decrease in the southern Makarov Basin because a large amount of sea ice meltwater covers that region and might decrease the nutrient supply from the subsurface layer.

Keywords: Siberian Arctic nutrients and chl-a

Oral presentation

Sinking particle flux of siliceous phytoplankton and the relationship with oceanographic variation in the southern Northwind Abyssal Plain

Onodera J., Watanabe E. and Harada N.

In order to study the relationship among sinking particle flux, siliceous microplanktons, and sea-surface water masses, sinking particle flux of siliceous phytoplankton and the species composition were observed in the western Arctic Ocean. Sinking particle samples were taken by bottom-tethered sediment trap at Station NAP (75°N 162°W) in the southern Northwind Abyssal Plain during October 2010-September 2012. Sinking particles mainly composed of lithogenic materials showed the annual flux maximum in November-December 2010 and 2011. The diatoms in November-December were mainly composed of *Chaetoceros* (subgenus *Hyalochaete*) and their resting spores. These results suggest the significant input of shelf side materials to the study area. Physical oceanographic model showed that cold eddy from off Point Barrow to the study area took a significant role in shelf material transportation to basin in November 2010. Maximum diatom flux in summer 2011 was clearly observed with dominance of sea-ice species *Fossula arctica*, whereas that in summer 2012 was quite low. Contrast to decreased diatom and other particle fluxes in 2012, sinking fluxes of silicoflagellate skeleton, which was secondary component of siliceous phytoplankton, were similar in 2011 and 2012. Therefore silicoflagellate abundances relatively increased to diatoms in 2012. The suppressed particle fluxes in 2012 were probably due to limited nutrient supply by intensified halocline and/or possible extent of oligotrophic Beaufort Gyre water to Station NAP in winter 2011-2012. In case of 2012 without summer flux maximum, contribution of transported shelf materials will be significant to annual budget of particulate organic carbon and lower ecosystems around the study area.

Keywords: diatom, sinking particle flux, Arctic Ocean

Poster presentation

Future of Arctic Ocean ecosystem and its climatic drivers

Popova E., Yool A., Robinson, J. and Kelly S.

The Arctic Ocean is a region that is particularly vulnerable to the impact of climate change. In this study, we use an ocean general circulation model, with embedded biogeochemistry and a full description of the carbon cycle, to study the response of ocean ecosystems to changing climate in the Arctic Ocean. Particular attention is paid to the strong regional variability within the Arctic and, for comparison, simulation results are contrasted with those for the global ocean. Simulations were run to year 2099 using the RCP 8.5 (the highest IPCC AR5 CO₂ emission scenario). Strong haline stratification of the AO and substantial ice cover suppress vertical mixing and restrict the vertical supply of nutrients to the photic zone. In such a vertically stratified oligotrophic system, the horizontal supply of nutrients by advection plays an important role in sustaining primary production. We present model experiments demonstrating that advective timescales linking subsurface layers of the central AO with the nutrient rich Pacific and Atlantic waters do not exceed 15-20 years, and that the advective supply of shelf nutrients to the deep AO occurs on the timescale of about 5 years. We show substantial role of the continental shelf pump in sustaining up to 20% of total AO primary production. However the role of advection is not restricted to the nutrient supplies. We use lagrangian methodologies in order to assess feasibility of penetration of Pacific planktonic species into the North Atlantic under the conditions of reduced ice cover.

Keywords: Arctic, climate change, ocean ecosystems

Oral presentation

Quantitative PCR and pyrosequencing of micro-eukaryote SSU amplicons reveal relative importance of *P. pouchetii* in diet of *Calanus* sp. (Maxillopoda:Calanoida) in coastal and pelagic ecosystems

Ray J.L., Skaar K.S., Simonelli P., Larsen A., Sazhin A., Jakobsen H.H. and Troedsson C.

An important component of marine ecosystem dynamics is the trophic interaction between phytoplankton primary production and mesozooplankton grazers. The marine microalgae *Phaeocystis* sp. is one of the most abundant primary producers in the high-latitude oceans. Nevertheless there is considerable uncertainty about its importance as a nutritional source for zooplankton. Without being able to more accurately quantify its importance, we cannot predict the broader impact of climate-induced changes in the spring bloom phytoplankton communities in the future ocean. Available data suggests that classical methods like gut chlorophyll-a measurements strongly overestimate its importance in zooplankton diet. This profoundly limits our knowledge on marine trophic relationships by biasing models and fish recruitment estimates. We have conducted a controlled mesocosm study and a research cruise in the Barents Sea to investigate the importance of *P. pouchetii* in the diet of *Calanus* sp. using molecular methods. We utilised a combination of 5'-nuclease assays (78 bp target) and next generation amplicon sequencing (V7 region of the SSU rRNA gene) to quantify *P. pouchetii* and to assess total diversity of micro-eukaryote communities, respectively, present in seawater and in *Calanus* sp. gut content.

Mesocosm experiment. During a *P. pouchetii* stimulated bloom, qPCR results targeting *Phaeocystis* in the gut of *Calanus* demonstrated that clearance rates on all sampling dates were $< 1 \text{ mL ind.}^{-1} \text{ day}^{-1}$. Results from ^{18}S rRNA amplicon library sequencing from *Calanus* gut content confirm this result with low abundances of *P. pouchetii* amplicons relative to total amplicon diversity. Gut content from all copepods contained mainly cercozoan, alveolate and stramenopile sequences in addition to many other microeukaryotic phyla, demonstrating a high diversity of prey organisms.

Research cruise. From seawater and copepods sampled at locations with different hydrological profiles, we identified low clearance rates ($< 1 \text{ mL ind.}^{-1} \text{ day}^{-1}$) at all stations with the exception of one station in outer Porsangerfjorden, where clearance rates were several orders of magnitude higher than at the other stations ($20\text{-}75 \text{ mL ind.}^{-1} \text{ day}^{-1}$). However, the same station had been sampled 33 hours earlier, but with considerably lower clearance rates of *P. pouchetii* by *Calanus* sp. ($< 1 \text{ mL ind.}^{-1}$). Neither differences in *P. pouchetii* density nor differences in temperature between the two casts could explain this difference.

Conclusions. These results indicate that despite colony formation, *Phaeocystis* can be an important part of the *Calanus* sp. diet in nature, although the mechanistic understanding of this interaction requires further investigation, particularly in the context of future oceans. Nevertheless, results are in agreement with the metastudy conducted by Nejstgaard et al. (2007), which concludes that overall feeding of small crustaceans on *Phaeocystis* spp. is lower in the field than can be observed in laboratory experiments. Molecular methods are a powerful tool for in situ general and specific studies of trophic interactions within the lower tiers of the marine food web.

Keywords: *Phaeocystis*, *Calanus*, mesozooplankton, grazing, qPCR, pyrosequencing
Oral presentation

Common strangers – year round study of meroplankton in Adventfjorden, Svalbard

Stübner E., Søreide J. and Lønne O.J.

Meroplankton are mainly comprised of larvae of benthic organisms and common in the zooplankton community. In periods, they occur in high abundances. Since many of them are small, they are easily underestimated using a standard net with 200 µm mesh size, and in general received little attention.

This study investigates Arctic meroplankton throughout a whole year. Samples with a 60 µm mesh size WP2 net were taken bi-weekly or monthly from December 2011 until December 2012 at a station close to the mouth of Adventfjorden on the west coast of Svalbard.

Meroplankton comprised around 76% (abundance) of the total mesozooplankton community summed up over the year. Bivalvia veliger larvae and Cirripedia nauplii together contributed 99% of the total number of meroplankton organisms found during the year.

Abundances and taxonomic composition of meroplankton within the zooplankton samples varied considerably throughout the year, with peak abundances during end of April until July. Different organism groups showed different timing schemes for larval occurrence. Larvae of cirripedes and bivalves had mass occurrences - periods where they numerically dominated the zooplankton community. These periods of dominance were surprisingly long (late spring to early summer). Polychaete larvae showed high abundances between the two main peaks of cirripede occurrence. Gastropoda were present in low abundances throughout most of the year, while Bryozoan larvae were present in low abundances from autumn until early spring. The appearance of meroplankton groups is analyzed taking life history, hydrography and timing of the spring bloom into account.

Keywords: meroplankton, seasonality

Oral presentation

Swordfish towards the arctic atlantic in climate change

Sundby S., Nøttestad L., Myklevoll S. and Tangen Ø.

The remarkable increase in abundance of swordfishes (*Xiphias gladius*) along the Norwegian coast is coinciding with the recent temperature increase in the North Atlantic Ocean since the cold period during the 1960s and 1970s. This increase is mainly due to the large-scale natural climate oscillation of the Atlantic Multidecadal Oscillation (AMO). The major part of the swordfishes occurred during late summer, particularly in August when sea temperature is at maximum. The swordfishes along the Norwegian coast seem to be solitary juvenile visitors and have all been within a limited size group from 1.5 to 2.65 m in length and from 20 to 40 kg in weight most probably corresponding to ages of 3-4 years. Younger fish would probably be too small for these long excursions to the north, but it is not clear why older and larger individuals stay away from the northern fringes of the distribution area. This is a different behavior from the bluefin tuna (*Thunnus thynnus*) in earlier periods, particularly in the 1950's and 60's.

Keywords: swordfish, migration, Norwegian coast, AMO

Oral presentation

Energetic costs for the Arctic copepod *Calanus glacialis* during overwintering

Søreide J.E., Daase M., Hatlebakk M., Boissonnot L., Freese D., Niehoff B. and Graeve M.

Calanus glacialis comprises up to 90% of the zooplankton biomass in Arctic shelf seas and plays a key role in Arctic marine ecosystems. It is primarily a grazer, accumulating essential polyunsaturated fatty acids from its algal diet as well as converting low-energy carbohydrates and proteins in algae into high-energy wax ester lipids. It is able to survive long periods without food by descending to depth and lower its metabolism to a minimum, referred to as diapause. The energetic costs during diapause are, however, poorly known despite that *C. glacialis* may be in this physiological state for up to 8 months a year. We therefore initiated an extensive field campaign in a high-Arctic fjord, sampling the same population monthly from June 2012 to July 2013, to estimate its monthly carbon demand by measuring its respiration. The carbon demand differed among *C. glacialis* CIV, CV, females and males over the winter with CV and adults being active much earlier than expected due to molting and reproduction. Of the developmental stages, only CIV seems to stay in diapause over an extended period, utilizing little of its lipid storage from fall through winter. The *C. glacialis* population declined steeply from January to May which can be explained by individuals running out of energy, although predation also has to be taken into account. Knowledge on species physiology and main stressors during the long Arctic winter is poor, but crucial to predict future ecosystem scenarios under climate change.

Keywords: Respiration, diapause, mortality, lipid storage,

Oral presentation

Inorganic Carbon Cycling and the Biogeochemical Processes in Hudson Bay

Pengelly L., Thomas H., Burt W., Miller L. and Papakyriakou T.

Coastal seas, like Hudson Bay, are biogeochemically active areas with high primary productivity. High productivity can be expected to lead to fractionation of $^{13}\text{C}/^{12}\text{C}$ creating depletion of ^{12}C isotope of Dissolved Inorganic Carbon ($^{12}\text{CDIC}$) in the surface and enrichment of $^{12}\text{CDIC}$ in deeper waters. The increase of anthropogenic CO_2 concentration can have drastic impacts on the biogeochemical properties of the ocean. Since the Arctic and coastal seas are primarily sensitive to these changes, assessing the carbon cycle of this area is very important for future studies. We present the carbon cycle and related data from the Arctic Net 2010 Cruise. We investigate and assess the processes governing the carbon cycle over the entire water column of Hudson Bay. We find that the deep waters of Hudson Bay are Pacifically derived and do not interact with Atlantic waters beyond the mouth of the Bay. River input greatly affect the waters of Hudson Bay. Also, the longer residence time of the deep Hudson Bay waters allows the accumulation of products due to various biogeochemical and physical processes. These include respiration of organic matter, which causes greater DIC and lower $\delta^{13}\text{C}$ values at depth, and brine formation, which increases salinity, DIC and alkalinity. The eastern side of Hudson is observed to have greater DIC concentrations and is isotopically lighter in $\delta^{13}\text{C}$ than the western side.

Keywords: Hudson Bay, CO_2 , carbon isotopes

Poster presentation

Historical diets, food web dynamics and climate in the Arctic

Townhill B.L., Pinnegar J.K. and Maxwell D.L.

Atlantic cod *Gadus morhua* stocks in the Barents Sea are currently at levels not seen since the 1950s, however it is unclear how these very high population numbers can be supported in terms of prey availability. High predatory cod numbers may also have consequences for other important commercial fish such as herring and capelin. Analysis of historical stomach data in the region has shown that cod diets have varied considerably over these decades and even year-on-year, with the importance of fish and invertebrate prey varying between years. Detailed analysis and modelling has been carried out using a set of biological and hydrographic datasets for the Bear Island (Spitsbergen) region between the 1930s and 1950s. Spatial, temporal and environmental factors all play a part in influencing the prey availability for cod and the overall stock abundance. Developing an understanding of historical food web dynamics, and in particular relationships between climatic conditions and diet, can enable predictions of how future changes might impact fisheries. This study has placed changes in cod diet in a context of both warming and cooling periods, changes in fishing mortality as well as changes in the availability of particular prey organisms (e.g. euphausiids, capelin, herring). As the Arctic is highly sensitive to climate change, but is also fished by many nations, the results of this project are directly relevant to future management of cod stocks.

Keywords: climate change, Arctic, foodweb, Atlantic cod

Poster presentation

Atmospheric forcing resulted in enhanced microbial production in the water column of the Chukchi Shelf, western Arctic, in early autumn

Uchimiya M. and Motegi C.

As a part of a study to investigate the response of ocean physics and ecosystems to atmospheric forcing in the ice-free Arctic Ocean, we examined temporal variability in prokaryote production rates (PP; 3H-leucine incorporation rate) at a fixed station in the Chukchi Shelf (71.75°N, 168.75°W), western Arctic, over 14 days in September of 2013. PP data were collected at a 6-hour interval (total number of samples = 429) throughout the water column (maximum depth, 52 m). Our data revealed that atmospheric cooling, accompanied by strong wind events, led to an increase in chlorophyll a (chl a) concentrations, which appeared to be due to enhanced supply of nutrients from below the pycnocline. In the euphotic zone, PP increased 2-fold (from 0.5 to 1.1 $\mu\text{g C L}^{-1} \text{d}^{-1}$) concomitant with an increase in chl a concentrations (from 0.3 to 1.0 $\mu\text{g L}^{-1}$) and a decrease in temperature (from 3.2 to 1.4°C): Pearson's correlation coefficient (r) between PP and chl a was 0.80 ($p < 0.001$), whereas that between PP and temperature was -0.70 ($p < 0.001$). These data indicate that the low temperature of the Arctic shelf did not inhibit a dynamic response of PP to the phytoplankton bloom, which was presumably associated with enhanced supply of organic substrates. In the aphotic zone, PP was negatively correlated with transmittance ($r = -0.50$; $p < 0.001$), interpreted as an indication that PP responded to sediment resuspension and concomitant supply of labile organic matter available for heterotrophic consumption. Taken together, our data provide evidence in support of the notion that atmospheric forcing can exert a large influence on microbial production, in both the euphotic and aphotic zones, of the ice-free Arctic shelf in autumn.

Keywords: Arctic Ocean, atmospheric forcing, prokaryote production

Poster presentation

Breeding later at higher latitudes: explaining seabird phenology along a latitudinal gradient from the Norwegian to the Barents Sea

Burr, Z., Varpe, Ø. and Anker-Nilsen, T.

Phenology links species to their physical and biological environments. Because environmental conditions vary by location it is expected that the timing of annual events would vary over a large geographic region, both within and between species. Seasonality generates a latitudinal gradient in environmental conditions to which we expect seabird adaptations to have evolved. This study investigates the timing of breeding of four seabird species (*Fratercula arctica*, *Rissa tridactyla*, *Uria aalge*, *Uria lomvia*) from multiple colonies covering a marginally Subarctic to Arctic latitudinal gradient along the Norwegian coast to Svalbard (65–79°N). We also present and discuss potential explanations for the observed patterns in breeding times, focusing on the phenology of lower trophic levels. A linear mixed-effects model with a random year effect revealed that hatching times within species were significantly delayed with latitude for all species (the two *Uria* species were treated together as *Uria* spp.) with mean hatch date delayed by 1.71, 2.14, and 1.50 days per latitudinal degree for *F. arctica*, *R. tridactyla*, and the *Uria* spp., respectively. A linear model of the timing of the spring phytoplankton bloom onset based on ocean color satellite data revealed a bloom onset delay by 3.27 days per latitudinal degree over a similar study region (62–78°N). We additionally discuss that the timing of the arrival of fish larvae with northward moving currents to seabird foraging grounds during the breeding season may be a contributor to the evolution of the observed seabird breeding times. Quantifying spatial patterns in timing and the discussion of the potential mechanisms for these trends need to be understood in order to recognize potential risks to successful breeding and to monitor future change.

Keywords: seabirds, breeding phenology, latitude, spring bloom

Poster presentation

Session E2: Detecting, projecting and managing the impacts of change in Southern Ocean ecosystems

Oral Presentations

Wednesday 25 June, 16:00-17:30 Parallel session 6

Chair: Eugene Murphy

Room K1

Time	Presenter	Title
16:00-16:15	Cavanagh, Rachel	Scenarios of change in the Southern Ocean
16:15-16:30	Voelker, Christoph	Scenarios for future physical and lower trophic level changes in the Southern Ocean until the end of the century
16:30-16:45	Cabre, Anna	A Latitudinally-Banded Phytoplankton Response to 21st Century Climate Change in the Southern Ocean across the CMIP5 Model Suite
16:45-17:00	Groeneveld, Jürgen	Using individual-based models to explore the potential of Antarctic krill to cope with climate change considering its chronobiology
17:00-17:15	Hofmann, Eileen	The Effects of Changing Winds and Temperatures on the Oceanography of the Ross Sea in the 21st Century
17:15-17:30	Bellerby, Richard	Southern Ocean ecosystems and ocean acidification

Thursday 26 June, 14:00-15:30 Parallel session 7

Chair: Andrew Constable

Room K1

Time	Presenter	Title
14:00-14:15	Hill, Simeon	Using existing Southern Ocean ecosystem models to project the impacts of change: capabilities, limitations, and progress required.
14:15-14:30	Constable, Andrew	Using observations of Southern Ocean ecosystems for managing krill fisheries, marine protected areas and for assessing the likelihood of different ecosystem scenarios in the future.
14:30-14:45	Godø, Olav Rune	Observing krill dominated ecosystems at scales that resolve key processes - an essential approach to ecosystem assessment and management
14:45-15:00	Österblom, Henrik	Ecosystem based management of marine systems – examples from the Southern Ocean and elsewhere
15:00-15:30	All	ICED Panel Discussion – Challenges for evidence-based management of Southern Ocean ecosystems

Session E2: Southern Ocean ecosystems

Poster Presentations

Wednesday 25 June, 17:30, Poster Session 2

Chair: Nadine Johnston

ID	Presenter	Title
E2.P1	Hofmann, Eileen	Processes Regulating Iron Supply at the Mesoscale (PRISM) Project
E2.P2	Kaufman, Daniel	A Glider-based Study of Biogeochemical Variability in the Southern Ross Sea
E2.P3	Silva, Carolina	Distribution of the surface chlorophyll concentration in the polar upwelling in the South Atlantic sector of the Southern Ocean
E2.P4	Park, Jisoo	Physiological limitation of phytoplankton photosynthesis in the Amundsen Sea, Southern Ocean
E2.P5	Salmon, Elodie	NPZD-iron lower trophic level model of the Ross Sea: Processes controlling the seasonal cycle of biological production.
E2.P6	Ryabov, Alexey	An ontogenetic krill model
E2.P7	Rackebrandt, Siri	A conceptual model to describe the population dynamics of Antarctic krill
E2.P8	Piñones, Andrea	Transport and fate of Euphausiid larvae in the Ross Sea
E2.P9	Tarling, Geraint	Defining the function of krill swarms from their level of roughness
E2.P10	Roura, Ricardo	A Marine Protected Area in the Weddell Sea, Antarctica: A proposal by environmental non-governmental organisations
E2.P11	Hall, Julie	Climatic variability in the Ross sea region of Antarctica and its potential influences on marine ecosystems
E2.P12	Johnston, Nadine	Rediscovering the Discovery Investigations (1925-1951): Extending our knowledge into the past to understand the future
E2.P13	Holan, Jessica	Increased sensitivity to contaminants and risk to sub-Antarctic marine invertebrates under predicted climate change scenarios

Southern ocean ecosystems and ocean acidification

Bellerby R., Lo Monaco C., Lovenduski N., Lenton A., Haruko K., Trimborn S., Hoppema M., Suckling C., Meridith M. and Sparrow M.

A major, potential stressor of marine ecosystems is the changing water chemistry following the present and simulated future increase in seawater carbon dioxide (CO₂), concentration. Increasing CO₂ causes a lowering of pH and a re-organisation of the marine carbonate system, commonly termed ocean acidification. Global average long-term ocean acidification projections are intimately linked with future atmospheric CO₂ levels, however the local expression of this global ocean acidification is much more heterogeneous, as local oceanic processes alter the average expectations of future ocean acidification. Evidence has mounted over the past years showing the importance of these 'bottom-up' local oceanic processes, both natural and anthropogenic, to altering the rate of ocean acidification from the long-term atmospheric top-down perspective. The challenges for Southern Ocean acidification are advancing the observations and constraints at understanding the underlining natural variability and the mechanisms that drive it, which are still poor. Pelagic ecosystems are changing fast, especially in the productive, euphotic zone. Autotrophic production may be changing in the surface Southern Ocean through increased primary productivity and a changing stoichiometry of oceanic primary production. This will have consequences both for energy flow and nutrient transport though Southern ocean ecosystems. Calcifying plankton, such as pteropods, have been shown to be adversely effected by current Southern Ocean acidification. These organisms are prominent players in the Southern Ocean ecosystem both as predator and prey, and control to a significant degree the export of carbon and other elements to the intermediate and deep ocean. There is concern over the future of polar marine organisms that are uniquely adapted towards their extreme and cold surroundings. In an environment where development is ten times slower than that in warmer regions of the world, the ability of these (mostly benthic) organisms to adapt to these changing conditions is questionable. Responses of benthic ecosystems have generally resulted in negative impacts (smaller size, slowed growth and high levels of abnormal development. There is a growing international effort to observe and monitor the marine carbonate system with the emphasis moving away from purely physic-chemical approach to an integrated observing system approach based on ecosystem-carbon-climate coupling. Additionally, coupled biogeochemical-ecosystem modeling efforts are becoming much more unified and assimilated through both a multi-model approach and that regional models are becoming much more to the fore. SCAR has appointed an international ocean acidification Action Group to document the scientific understanding of ocean acidification. This presentation will inform on the latest knowledge of chemical and biological consequences of ocean acidification in the Southern Ocean through an ecosystem and earth system approach. It will also identify important gaps in current research and propose approaches to gain a better understanding of the rates, effects and feedbacks of future ocean acidification. New understanding on Southern Ocean Acidification will be assessed in light of the recent findings of the AMAP Arctic Ocean Acidification report.

Keywords: Southern Ocean, Ecosystem, Ocean Acidification, SCAR
Oral presentation

A Latitudinally-Banded Phytoplankton Response to 21st Century Climate Change in the Southern Ocean across the CMIP5 Model Suite

Cabre A., Leung, S. and Marinov. I.

The response of Southern Ocean phytoplankton productivity to climate variability and to 21st Century climate change is investigated across the CMIP5 earth system model suite. Iron and light supply (controlled by cloud cover, mixed layer depth during blooms, and sea ice concentration) are shown to be the relevant limiting factors in the subpolar and polar Southern Ocean, consistent with previous studies. Via correlation analyses, we find that shifts in these limiting variables drive changes in phytoplankton production on interannual, decadal, and 100-year timescales. On a 100-year timescale, production trends show a latitudinally-banded pattern with macronutrient decreases north of 40°S driving decreases in production; iron and light increases from 40-50°S and south of 65°S driving increases; and iron and light decreases from 50-65°S also driving decreases. We further investigate whether these banded patterns can ultimately be attributed to an increasingly positive SAM index. Our results suggest that ocean dynamical changes driven by SAM will play a significant role in altering Southern Ocean phytoplankton productivity patterns on the timescale of 21st Century climate change.

Keywords: Southern Ocean, primary production, climate change, CMIP5 models

Oral presentation

Scenarios of change in the Southern Ocean

Cavanagh R.D., Murphy, E.J., Turner, J., Bracegirdle, T. J., Philips, T., Knowland, C., Underwood P. and N.M. Johnston

Southern Ocean ecosystems are integral to the Earth System, influencing global climate and biogeochemical cycles and maintaining unique biodiversity and ecosystem services. They are currently undergoing rapid climate-driven changes. Given the knowledge gaps and uncertainties inherent in studying the effects of change on marine ecosystems, we report on the development of a set of community-agreed scenarios for the Southern Ocean from which to explore the potential responses to and consequences of change. These include quantitative scenarios of sea ice change and other key environmental parameters, together with qualitative scenarios (including the recovery of key species). We highlight issues involved in the development of these scenarios, explore the associated uncertainty, and provide guidance in applying them (e.g. which regions to focus on with respect to understanding particular drivers of change). These scenarios will provide a basis for exploring potential impacts of change on key species and the whole ecosystem, provide a framework from which to develop projections of future change in the region, and will be used to inform both IPCC and CCAMLR regarding Southern Ocean change and management.

Keywords: ecosystems, scenarios

Oral presentation

Using observations of Southern Ocean ecosystems for managing krill fisheries, marine protected areas and for assessing the likelihood of different ecosystem scenarios in the future.

Constable A., Melbourne-Thomas J., Kawaguchi S., Southwell C., Emmerson L. Ziegler P. and Corney S.

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) adopts management measures for the krill fishery, marine protected areas and conservation of Antarctic marine biota on the basis of the best scientific evidence available. While it has adopted a precautionary approach to management, it also has established the CCAMLR Ecosystem Monitoring Program to provide data to feed back into the management of the krill fishery. More recently, it has identified a need to establish programs to observe long-term change in Southern Ocean ecosystems and programs to monitor marine protected areas. This presentation will consider how recent initiatives to develop observing systems in the Southern Ocean could be used to enhance CCAMLR's approach to management. These initiatives include an expanded CCAMLR Ecosystem Monitoring Program, the Southern Ocean Observing System and ICED's Southern Ocean Sentinel. Further, recent consideration of ecosystem Essential Ocean Variables (eEOVs) to be measured systematically may enhance the capacity to cost-effectively measure change in these ecosystems. The presentation will focus on how these initiatives may contribute to the feedback management of the krill fishery at both strategic and tactical levels.

Keywords: Antarctica, Southern Ocean, CCAMLR, conservation

Oral presentation

Observing krill-dominated ecosystems at scales that resolve key processes – an essential approach to ecosystem assessment and management

Godø O.R.

Strong gradients and dynamics in ocean physics of high latitude marine ecosystems create ecological responses that are difficult to observe and predict. Accordingly, identifying and assessing human impacts in ecosystem management is challenging. Simple ecosystems like those found in the krill dominated Antarctic should in principle be easier to model and predict compared to complex multispecies ecosystem in more temperate and tropical areas. However, without a more complete understanding the physical driving mechanisms behind krill distribution and abundance, prediction has to be based on statistical relationships that in most cases will not reflect the actual processes behind the observations.

In this presentation I consider the variability experienced in the krill fisheries and surveys and present observation solutions that might facilitate a better basis for understanding and predicting krill dominated ecosystems. Acoustic based sensors operated in an extended infrastructure including fisheries and scientific vessel capacity can contribute a data stream that resolves information on scales from millimetre to kilometre including individual behaviour and interactions as well as collective dynamics. In remote areas like the Antarctic we need sensors, platforms and networks operating autonomously and collecting information about processes at time and scales on which they occur. Most important, the key to better observation and modelling is development of platforms and operation facilities that position sensors on the right spot to the right time. Finally, the success of taking enhanced observation capabilities into use requires a tight interaction between technologists and modellers. Technologists must inform modellers of the opportunities offered by the technology, while the modellers need to describe key challenges such as establishment of model parameters that needs observations and/or validation. The remoteness and extensiveness of the Southern Ocean leave us few other options than building partnerships among all actors and utilizing emerging technologies. Thereby we may enhance and maintain a knowledge based ecosystem management under the experienced and expected climatic variation and trends.

Keywords: observation systems, acoustics, partnerships, ecosystem management

Oral presentation

Using individual-based models to explore the potential of Antarctic krill to cope with climate change considering its chronobiology

Groeneveld J., Johst K., Meyer B., Kawaguchi So., Teschke M. and Grimm V.

We investigate how individual growth and population structure of Antarctic krill (*Euphausia superba*) would be affected by changes in the spatio-temporal dynamics of the sea ice cover. This is of high interest since krill has adapted to a particular environmental regime which is likely to change dramatically over the coming years. The response of krill will in particular depend on its chronobiology: when and why does krill, after a period of decreased metabolic activity during winter, switch back to an active metabolic state? If this switch is purely triggered by the Zeitgeber day length, the metabolically active period of krill and the availability of food resources would become out of phase with potentially drastic consequences for krill populations. Alternatively, the switch might also be triggered by food availability. To explore the consequences of different environmental scenarios and assumptions about krill chronobiology, we developed a spatially explicit individual-based simulation model. The model operates on a daily time step. Each time step ice cover extent and day length for each grid cell in the model are updated. In the model demographic and behavioural processes are simulated every time step. Particularly all modelled krill individuals grow depending on food availability, move, reproduce given their reproductive and metabolic state, and die with a certain probability. Growth and reproduction are modelled according to a simplified version of dynamic energy budget theory (DEBKiss). Simulations run for several years until quasi-stationary population characteristics have emerged. Population metrics such as length distribution and heterogeneity in reproductive state within the population are observed. We will present the model and demonstrate its potential by contrasting results for selected environmental and chronobiological scenarios. The model's design and implementation are open so that suggestions regarding alternative assumptions and scenarios can easily be implemented and explored.

Keywords: *Euphausia superba*, simulation, seasonality, ice cover

Oral presentation

Climatic variability in the Ross sea region of Antarctica and its potential influences on marine ecosystems

Williams M.J.M., Dean S.M., Rickard G.J., Bowden D.A. and Pinkerton M. Presented by [Hall J.](#)

Climate change will affect marine environments of the Ross Sea region in the coming century. Understanding ecosystem response to climate variability is of fundamental importance to precautionary management in the region, but linkages between the physical environment and ecosystem dynamics remain poorly understood. We describe a research programme which aims to explore likely future changes in the physical environment of the region and potential consequences of these for marine ecosystems. The research has four parts, spanning all aspects of the regional ecosystem from past and present climate and physical oceanography to primary production, export to the benthos, and the dynamics of top predators. Here, we present progress in development of a fine-scale regional ocean model and the use of climate and sea-ice records from the instrumental era to evaluate IPCC AR5 global climate models specifically for the Ross Sea region. We will use projections developed from the best-performing of these models to constrain the regional model, generating a number of future environmental envelopes with which we will explore potential future states of the Ross Sea ecosystem.

Keywords: Climate change; Ross Sea; CMIP5; ecosystem

Poster presentation

Using existing Southern Ocean ecosystem models to project the impacts of change: capabilities, limitations, and progress required.

Hill S., Ballerini T., Hinke J., Phillips T. and Watters G.

Several existing marine ecosystem models represent the effects of physical variables, such as sea temperature, on ecological processes in the Southern Ocean. Others represent the propagation of changes through the food-web. Such models are useful for projecting the ecosystem impacts of fisheries-driven and climate-driven change. We demonstrate the capability of existing models by using sea temperature projections from climate models to drive an empirical krill growth model which, in turn, drives a krill-predator dynamic model. This chain of linked models projects the possible consequences of plausible warming for predator populations in the Scotia Sea and southern Drake Passage. Rather than attempting to model the cumulative effects of all interacting ecological processes, this approach considers the marginal effects of a specific pathway and allows an assessment of the sources of uncertainty at each stage. The level of uncertainty in most ecological projections is very high and progress is necessary to improve the description of ecological processes and the quantification of uncertainty. The current generation of models is useful for assessing the potential broad impacts of climate change, but future models will need to support local adaptation. This requires increased cooperation between scientists, policy makers and other interested sectors to identify the specific objectives of such models.

Keywords: Southern Ocean, climate change, ecosystem mode

Oral presentation

The Effects of Changing Winds and Temperatures on the Oceanography of the Ross Sea in the 21st Century

Hofmann E.E., Smith W.O. Jr, Dinniman M.S. and Klinck, J.M.

The Ross Sea is critically important in regulating Antarctic sea ice and is biologically productive, which makes changes in the region's physical environment of global concern. We examined the effects of projected changes in atmospheric temperatures and winds on aspects of the ocean circulation likely important to primary production using a high-resolution sea ice–ocean–ice shelf model of the Ross Sea. The modeled summer sea ice concentrations decreased by 56% by 2050 and 78% by 2100. The duration of shallow mixed layers over the continental shelf increased by 8.5 and 19.2 days in 2050 and 2100, and mean summer mixed layer depths decreased by 12 and 44%. These results suggest that the annual phytoplankton production in the future will increase and become more diatomaceous. Other components of the Ross Sea food web will likely be severely disrupted, creating significant but unpredictable impacts on the ocean's most pristine ecosystem.

Keywords: Ross Sea, climate change

Oral presentation

Processes Regulating Iron Supply at the Mesoscale (PRISM) Project

McGillicuddy D., Dinniman M., Sedwick P., Smith, W.O. Jr. and Greenan B.

Presenter: Hofmann E.

The Ross Sea continental shelf is the single most productive area in the Southern Ocean, but the processes that control the magnitude of primary production in this region are not well understood. Field observations and model simulations indicate four potential sources of dissolved iron to surface waters of the Ross Sea during the growing season: (1) Circumpolar Deep Water intruding from the shelf edge; (2) sediments on shallow banks and nearshore areas; (3) melting sea ice around the perimeter of the Ross Sea polynya; and (4) glacial meltwater from the Ross Ice Shelf. The relative contribution of these potential iron sources are being evaluated as part of the PRISM project using in situ observations collected during a multidisciplinary cruise in austral summer 2011/12, quantitative budget estimates, and numerical modeling studies. A dissolved iron budget constructed using data collected during the PRISM cruise, high-resolution model simulations of Ross Sea ice melt and circulation, and satellite-based estimates of primary production suggests that the primary sources of dissolved iron to the euphotic zone are wintertime mixing and melting sea ice, with a lesser input from intrusions of Circumpolar Deep Water, and a small amount from melting glacial ice. These combined sources provide enough dissolved iron to meet the biological demand inferred from satellite-based productivity algorithms, although there are considerable uncertainties in each of the estimates. Additional data analyses and modeling studies now underway are designed to further refine these results. This poster will provide an overview of the PRISM project and these studies.

Keywords: Ross Sea, iron, mesoscale, biological production

Poster presentation

Increased sensitivity to contaminants and risk to subantarctic marine invertebrates under predicted climate change scenarios

Holan J., King C. and Davis, A.

Stressors associated with climate change, and contaminants resulting from the activities of humans, are affecting organisms and ecosystems worldwide. Until recently, the impacts of these stressors on marine ecosystems have largely been examined in isolation. However, with predicted climate change, it is essential that the interactions between these stressors are known, so that the risks of contamination under present and future climate change scenarios can be determined.

High latitudinal species may be more susceptible to contamination and climate change than equivalent species in temperate and tropical areas. Detoxification of contaminants by polar species is likely to be slower due to slow metabolisms in colder climates. Organisms in polar regions also have characteristically small temperature tolerances through adaptation to relatively stable and low oceanic temperatures. Therefore, any increase in ocean temperature associated with climate change is likely to be particularly detrimental to marine ecosystems in these areas. Despite this, very little is known of how climate change stressors and contamination will affect Antarctic and subantarctic species, nor how these stressors will interact with each other in marine ecosystems worldwide.

Despite being relatively untouched, the subantarctic has endured many decades of human habitation leading to the accumulation of wastes and contamination in some areas. In addition, climate change in subantarctic marine environments is evident. On Australia's subantarctic Macquarie Island, temperature and rainfall are increasing. Not only will this create thermal and osmotic stresses, increased rainfall will potentially increase mobilisation of contaminants from the land into the intertidal zone. Near-shore marine assemblages are particularly at risk, due to both fuel spills associated with shipping, which often occur close to land, and to run-off of contaminants from terrestrial systems.

The effects of multiple stressors were investigated on intertidal marine invertebrates from a range of taxonomic groups collected from subantarctic Macquarie Island. Test species included the bivalve *Gaimardia trapesina*, the flatworm *Procerodes ohlini*, the sea cucumber *Pseudopsolus macquariensis* and an harpacticoid copepod. Copper was chosen as a representative contaminant as it is highly toxic to biota and is common at contaminated sites in polar environments. Replicate tests were run on each species to enable determination of point estimates such as median lethal concentrations (LC50s). Metal concentrations in test solutions were determined by Inductively-Coupled Plasma Optical Emission Spectrometer (ICP-OES). Once sensitivity to copper alone was determined, multi-stressor tests were conducted by exposing test organisms to a range of copper concentrations, and to several salinities and temperatures relevant to predicted climate change scenarios. Interactions between stressors were determined by comparing LC50s for each stressor combination, and by ANOVA. Sensitivity to copper was found to be amplified by increased temperature and reduced salinity. Concurrent with other regions of the world, this indicates that the interactive effect of contamination and climate change stressors will have major impacts on subantarctic marine invertebrates and ecosystems.

Keywords: Polar, ecotoxicology, temperature, salinity, marine invertebrates
Poster presentation

Rediscovering the Discovery Investigations (1925-1951): Extending our knowledge into the past to understand the future

Johnston N.M., Murphy E., Silk J.R.D., Waluda C.M., Hill S.L. and Ward P.

Historical data series that have been generated during the long history of Southern Ocean research represent a valuable resource with which to piece together information about long-term, large-scale ecosystem functioning, variability and change. They also offer a baseline of data against which we can assess current and future dynamics of ecosystems under scenarios of climate and anthropogenic-driven change. Such information can be used to underpin management strategies. As part of a continuing research effort, the British Antarctic Survey has been digitising and uniting the elements of the Discovery Investigations (1925-1951) collection into a single open access website for research and education. Here we present our progress to date, including analyses of the regional and circumpolar distribution and abundance of key macro-zooplankton groups which form much of the bases for the food web and an international fishery (Antarctic krill). We examine their relationships to environmental variables (e.g. sea temperature), and develop simple bioclimatic envelope models (or ecological niche models). We also explore ways to project the geographic ranges of plankton (from the 1920s to the current day) as a function of climate and validate these projections. These scientific analyses will contribute to wider international efforts to examine the impacts of past and future change in Southern Ocean ecosystems.

Keywords: macrozooplankton, historical, predictions, bioclimatic envelope models

Poster presentation

A Glider-based Study of Biogeochemical Variability in the Southern Ross Sea

Kaufman D.E., Friedrichs M.A.M., Smith Jr W.O., Queste B.Y. and Heywood K.J.

The Ross Sea supports substantial biological productivity characterized by marked seasonal variations in concentrations of the dominant *Phaeocystis antarctica* and diatom assemblages. Our understanding of small-scale biogeochemical patterns, the interactions responsible for these patterns, and their effect on lower trophic levels throughout the seasonal phytoplankton bloom is incomplete. The aim of this study is to characterize small-scale variability associated with the bloom and to investigate potential mechanisms driving change in the assemblage. High-resolution autonomous glider data (including temperature, salinity, oxygen, fluorescence, and optical backscatter) were collected along two glider sections near 76°40'S during the 2010-2011 austral summer. Sea surface temperatures were warmer and mixed layers deeper during the latter, westward section. Substantial quantities of Modified Circumpolar Deep Water (MCDW), identified by neutral density criteria, were identified during both sections. Chlorophyll (Chl) concentrations computed from fluorescence exhibited daily quenching and were periodically elevated at depths down to ~200 m, suggesting substantial export on small space and time scales. Particulate organic carbon (POC) concentrations computed from backscatter increased abruptly during the latter, westward section, concurrent with a decrease in chlorophyll. These higher POC:Chl ratios were not strongly correlated with presence of MCDW or with shallower mixed layer depths, but were strongly associated with higher surface temperatures and wind speed. The observed POC:Chl increase suggests a marked spatial and temporal transition between a *Phaeocystis antarctica*-dominated assemblage characterized by modest POC:Chl ratios to a diatom-dominated assemblage. A subsampling analysis highlights the unique capability of high-resolution glider data to resolve these biological/physical parameter correlations that are not discernible from lower frequency data typical of traditional cruise stations. Glider-based approaches like this can help provide key monitoring of biogeochemical dynamics in regions similar to the Ross Sea that are undergoing substantive climate-induced changes and where harsh conditions make other means of access difficult.

Keywords: Ross Sea; Phytoplankton; Glider; Modified Circumpolar Deep Water

Poster presentation

A Marine Protected Area in the Weddell Sea, Antarctica: A proposal by environmental non-governmental organisations

Nicoll R., Campbell S. and Roura R.M.

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the body that regulates fishing in Antarctica's Southern Ocean, is working on the establishment of a network of Antarctic Marine Protected Areas (MPAs). Environmental non-governmental organisations (ENGOS), under the umbrella of the Antarctic Ocean Alliance, are contributing to this work through the development of its own proposals for marine protected areas and no-take marine reserves in 19 specific areas in the Southern Ocean around Antarctica. Formed in 2011, the Antarctic Ocean Alliance is a coalition of 30 leading environmental organisations and high profile individuals calling for large-scale protection of critical marine habitats. The ENGO submissions have no formal status but are meant to inform official proposals by providing robust arguments for conservation planning based both on current scientific knowledge and scientific uncertainty, in accordance with the provisions of the 1980 Convention on the Conservation of Antarctic Marine Living Resources. This presentation describes the Alliance's vision for Weddell Sea region as outlined in its most recent report. It describes the Alliance's proposal and the rationale for the Weddell Sea's designation as a Marine Protected Area, including fully protected marine reserves. The Weddell Sea is a keystone in any future Southern Ocean conservation network, and its designation as a permanent, large-scale marine reserve would be an important and inspirational step for marine protection both in the Southern Ocean and globally. The Weddell Sea report is the fourth in a series of "Antarctic Ocean Legacy" proposals from the Antarctic Ocean Alliance since 2011. The "Antarctic Ocean Legacy" proposals call on CCAMLR to grasp the opportunity to establish the world's largest network of marine protected areas and no-take marine reserves in the oceans around Antarctica as a legacy for future generations – the most comprehensive regime of its kind on the planet.

Keywords: Southern Ocean, CCAMLR, Marine Protected Areas

Poster presentation

Ecosystem based management - examples from the Southern Ocean and elsewhere

Österblom H., Schultz L., Folke C. and Olsson P.

Ecosystem based management approaches represent an emerging paradigm in marine resource management. This approach requires a management structure that is adaptive to change and integrates a range of different and complementary sources of knowledge and capacity. This study describes three case studies on such adaptive management approaches, including a wetland landscape in Southern Sweden, the Great Barrier Reef in Australia, and fisheries management in the Southern Ocean. We compare the development of these initiatives and their effects on ecosystem services. Each initiative was developed to match the organizational level to the ecosystems in focus and has been strengthened by sanctioning and support from international and national institutions. In all three cases we find positive effects on bundles of ecosystem services and that adaptive management has enabled actors to collaborate and respond to changing conditions and negative trends. In all cases, an awakening crisis reframed the human-nature relationship among key individuals and actors, an umbrella concept mobilized knowledge and action across scales and sectors, and an existing or new bridging organization made the adaptive management and ecosystem based approach possible. The three cases have served as sources of inspiration for ecosystem services related policy and practice across the globe. However, internal changes and external drivers of global impacts and demands are increasingly challenging the long-term success of the initiatives.

Keywords: Adaptive management, CCAMLR, Ecosystem, fisheries, governance

Oral presentation

Physiological limitation of phytoplankton photosynthesis in the Amundsen Sea, Southern Ocean

Park J., Gorbunov M.Y. and Lee S.

The phytoplankton physiological parameters were measured by Fluorescence Induction and Relaxation (FIRe) system in the Amundsen Sea (west Antarctic) in early (2013/2014) and late (2011/2012) austral summer during the Korea Antarctic research cruises. These cruises were conducted as a Korea Polar Research Institute (KOPRI) Amundsen project. Three ice shelves, such as Dotson, Getz, and Pine Island Glacier, and two polynyas (Amundsen and Pine Island) belong to the study area. The FIRe physiological parameters provide an express diagnostics of the effects of environmental factors, including iron limitation, on photosynthetic processes. On-board FIRe measurements showed that the quantum efficiencies of photosystem II (F_v/F_m) in near-surface phytoplankton were highly variable both in space and time. To demonstrate that iron limited responses of natural phytoplankton assemblages, we carried out iron assimilation experiments (during more than seven days) at four different sites (open sea, outer shelf, polynya center, and front of ice shelf, respectively). Possible implications of iron limitation and controlling factors of phytoplankton growth in this polynya system are discussed.

Keywords: phytoplankton physiology, Amundsen Sea

Poster presentation

Transport and fate of Euphausiid larvae in the Ross Sea

Piñones A., Hofmann E.E., Dinniman M.S. and L. Davis B.L.

A coupled sea ice-ice shelf-ocean circulation model was used to simulate the circulation and the hydrographic conditions on the continental shelf of the Ross Sea. Lagrangian particle simulations using neutrally buoyant floats were used to simulate the transport of larvae of Antarctic krill (*Euphausia superba*) and Crystal krill (*Euphausia crystallorophias*), which are important components of the Ross Sea food web. The adults of both species occupy different parts of the shelf and have different reproductive strategies. The hypothesis tested with the particle tracking simulations is that the adult distributions are the result of oceanic circulation and the location of Circumpolar Deep Water (CDW), which influences the early life stages of Antarctic krill. Simulations showed particle aggregation in regions of the Ross Sea that were coherent with observed distributions of the abundance of juveniles and adults of Antarctic krill and Crystal krill. The time scales for the simulated particle trajectories that were retained on those regions were variable. About 60-70% corresponded to larvae and 30-40% were juveniles and adults. Input sources for *E. superba* were along the same regions where the particle simulations were initialized. However, for *E. crystallorophias* the origination regions appeared to be constrained to the outer shelf and deep troughs. Particles initialized in the innershelf off Victoria Land showed high retention in the region south and along the Terra Nova Bay polynya, with time scales consistent with development times of *E. crystallorophias*. These results suggest that ocean circulation contributes significantly to the dispersion and retention of crystal krill on parts of the continental shelf that overlap with top predator abundances. As well as it contributes to the transport and aggregation of Antarctic krill in regions where modified CDW is observed.

Keywords: Ross Sea, Antarctic krill, Crystal krill

Poster presentation

A conceptual model to describe the population dynamics of Antarctic krill

Rackebrandt S., Kohlmeier C. and Blasius B.

Polar regions are characterized by strong seasonal changes in environmental parameters such as light intensity and sea ice coverage. Antarctic krill (*Euphausia superba*) – a key species in the Southern Ocean – has adapted to these extreme changes by synchronizing its metabolism and behavior to the environment. Studies suggest that this synchronization depends on a complex interplay between an internal clock and external environmental cues. Most studies on effects of climate change on krill consider annual mean values and are therefore not suitable to capture the seasonal timing between krill and its environment. Hence, the process of synchronization between krill and its seasonally-changing environment is yet unknown.

We propose a conceptual model describing the population dynamics of Antarctic krill and its functional interactions with the polar environment. The model considers juvenile and adult krill feeding on pelagic and sea ice phytoplankton. The growth of the phytoplankton in turn depends on seasonally changing sea ice coverage, light intensity and nutrient concentrations. Our model is able to reproduce the general course of annual krill dynamics. Therewith, it provides a basis for studying the effect of climate induced changes in polar environments and the associated mismatch of biological timing for Antarctic krill, with consequences for the whole Antarctic ecosystem.

Keywords: Krill, model, population dynamics, biological timing

Poster presentation

An ontogenetic krill model

Ryabov A.

Antarctic krill (*Euphasia superba*) plays a central role in the Southern Ocean foodweb. However, the krill population dynamics is far from clear. The development of krill individuals is a complex non-uniform process, in which the influence of environmental factors on growth and survival changes with the ontogenetic stage of individuals. This is especially pronounced during winter, when adult krill can starve for a long time, while krill larvae can overwinter only due to the presence of ice algae. To investigate the dynamics of krill populations, we propose a model of krill ontogenetic development. In our model, cohorts of individuals pass through four basic stages: eggs-embryos, larvae, juveniles and adults. The growth and survival during each stage are characterized by a unique set of rules. The model follows principles of the dynamic energy budget theory and is parameterized according to contemporary field and lab data. The model is aimed to study the dependence of krill population dynamics on individual traits and on environmental factors, such as temperature, primary production, and sea ice duration.

Keywords: ontogenetic krill model

Poster presentation

NPZD-iron lower trophic level model of the Ross Sea: Processes controlling the seasonal cycle of biological production.

Salmon E., Dinniman M.S. and Hofmann E.E.

The seasonal cycle of phytoplankton production in the Ross Sea consists of large seasonal blooms that are typically dominated by colonial *Phaeocystis antarctica* in spring through early summer (November-December), with an increasing abundance of diatoms in mid- to late summer. During summer, macronutrients are abundant but dissolved iron concentrations are low, suggesting iron limitation as the regulator of phytoplankton growth in the Ross Sea. A simple biogeochemical model was embedded in a ROMS-based Antarctic coastal circulation model to identify processes controlling the seasonal cycle of phytoplankton production. This formulation includes explicit dynamics for iron, silicic acid and three groups of phytoplankton (*Phaeocystis antarctica* solitary cells and colonies and diatoms), two groups of zooplankton and detritus. The parameterizations used for primary production are revised to reflect physiological responses of Ross Sea phytoplankton communities. Simulation results suggest that phytoplankton growth is mainly controlled by light, mediated by sea ice cover, and dissolved iron availability. A smaller value of nitrate uptake rate is needed to reproduce fast growth of phytoplankton during the Antarctic spring season than in Arctic region. Starting in the fall, reduced incident radiation combined with increased sea ice cover halts biological production, providing time for hydrodynamic processes to reset the dissolved iron content of the upper water column from sources such as Circumpolar Deep Water, sediments on shallow banks and sea ice. A nitrogen budget is been developed in order to evaluate relative magnitudes of biological processes.

Keywords: NPZD-iron model, primary production, iron sources

Poster presentation

Distribution of the surface chlorophyll concentration in the polar upwelling in the South Atlantic sector of the Southern Ocean

Silva, C.E. and Samuelsen A.

Phytoplankton provides the foundation for all organisms in the marine ecosystem and changes in primary productivity could have a significant influence on biodiversity, fisheries and the human food supply. The Southern Ocean (SO), in general, presents low number of phytoplankton (standing stock) and high macro-nutrient concentration due to iron limitation. But, upwelling waters in the SO are relatively rich in inorganic nutrients and upon reaching the euphotic zone sustains a large productivity of phytoplankton. In addition mesoscale process at the fronts can transport iron and nutrients into the surface layer. Analyzing the distribution of the surface chlorophyll concentration in the area as a proxy for phytoplankton biomass, we investigated how the open-ocean upwelling in the Atlantic sector of the Southern Ocean influence the phytoplankton growth. For this purpose, we utilized satellite ocean color data, sea surface temperature and chlorophyll, from the Aqua Moderate Resolution Imaging Spectroradiometer (Aqua MODIS) to examine distributions of chlorophyll concentration within the Southern Ocean for the period July 2002 through July 2013. Wind stress from the ERA-40 reanalysis in addition to sea surface temperature is used to determine regions and periods of Ekman upwelling. The preliminary results shows phytoplankton blooms during the spring and summer seasons. The highest mean chlorophyll concentration ($0.7227\text{mg}\cdot\text{m}^{-3}$) was found in January, 2009 in the open-ocean upwelling region.

Keywords: Chlorophyll, Upwelling, Southern Ocean

Poster presentation

Defining the function of krill swarms from their level of roughness

Tarling G., Saunders R., Fielding S. and Thorpe S.

The distribution of swarms of Antarctic krill in space and time often has a dominating influence on trophic interactions and biogeochemical fluxes within the Southern Ocean. Antarctic krill are obligate swimmers but the size and shape of their swarms varies enormously from aggregations of tens of individuals to superswarms stretching many kilometres and containing hundreds of thousands of krill. Developing a capability to parameterise and predict swarm formations can provide a much greater understanding of Southern Ocean ecosystem operation. Recent evidence from marine acoustics has proposed that, across a range of different swarming and schooling species, the ratio of the surface-area to volume (termed R) converges around a constant value of 3.3. It is further hypothesised that this constant is the product of competing influences of predation threat, which encourages tighter, smoother aggregations (low R) and oxygen demand, which leads to disaggregation (high R). We examined the value of R in over 6000 Antarctic krill swarms in the open ocean region of the Scotia Sea, and on the South Georgian shelf, firstly, to ascertain whether the value remained constant across the wide range of swarms encountered and, secondly, to determine the best predictors of R from a range of explanatory variables. In smaller swarms (between 10 and 40 m²), R remained relatively constant at a value close to 3. However, with increasing swarm area (between 100 to 10,000 m²) R tended towards values closer to 1, indicating that larger swarms became smoother. Across all sizes of swarms, R was significantly lower in those found on the shelf compared to the open ocean. Furthermore, in the vicinity of South Georgia, R decreased significantly with decreasing distance to land. Both lines of evidence indicate a smoothing of swarm shape within areas of greatest threat from land-based predators such as seals, penguins and flighted-birds. In offshore regions, the best predictors of R were fluorescence and temperature, with R increasing positively with both parameters. Krill have often been reported to disaggregate when feeding, so a higher R in food rich-regions is consistent with this pattern. A greater level of disaggregation at higher temperatures is also consistent with the oxygen demand hypothesis given that oxygen saturation levels are lower in warmer waters and individual metabolic demand is higher. Co-variables such as individual size and maturity may also have an influence on these relationships. Overall, we propose that feeding is the main driver of swarm shape in the open ocean, but that the threat of predation becomes an increasingly important influence when further inshore. We obtained only indirect evidence on the disaggregating influence of oxygen demand, but our findings were consistent with this hypothesis. Such parameterisations can assist in the inclusion of important behavioural traits within ecosystem-level modelling approaches.

Keywords: *Euphausia superba*, predator-prey interactions, marine ecosystems

Poster presentation

Scenarios for future physical and lower trophical level changes in the Southern Ocean until the end of the century

Voelker C., Wolf-Gladrow D.A. and Hauck J.

Climate change will affect the Southern Ocean in many different ways, from the change in wind speed and more subtle shifts in wind patterns to changes in ocean circulation and mixing and in flow and basal melting of ice shelves, possibly even resulting in collapse of some shelves. Although these changes will all affect the higher trophic levels in the Southern Ocean ecosystem directly, they will also affect them indirectly, through changing the conditions for the lowest trophic levels, phytoplankton and the zooplankton that feeds on it. Ecosystem models are reasonably successful in describing the present-day spatio-temporal distribution of phytoplankton (although the Southern Ocean remains a more difficult spot on Earth to do so) but differ in the dominant control mechanisms, giving rise to uncertainty in their predictions under climate change.

Here we first discuss what controls Southern Ocean phytoplankton growth, its seasonality and biomass in our ecosystem model, in the context of Sverdrup's critical depth hypothesis vs. Behrenfeld's dilution-recoupling theory. A special focus is on the role of light acclimation and its iron dependency, as represented in our flexible stoichiometry model. We then discuss how this dominant control affects the outcome from a climate change scenario model run until the end of this century. By comparing to other models scenarios we attempt to bracket the range of possible changes, and to identify observations that will help to reduce the model spread.

Keywords: phytoplankton, climate change, light, nutrients

Oral presentation

Session E3: Biogeochemical and ecological impacts of boundary currents in the Indian Ocean

Oral Presentations

Tuesday 24 June, 11:00-12:30 Parallel session 1

Room D7

Time	Presenter	Title
11:00-11:30	Hood, Raleigh	Biogeochemical and Ecological Impacts of Boundary Currents in the Indian Ocean
11:30-11:45	Wiggert, Jerry	The Influence of Upwelling and Boundary Current Dynamics on Biogeochemical Variability in the Eastern Indian Ocean
11:45-12:00	Waite, Anya	Living on the Edge of the Predator Pit: Nutrition and Oceanic Habitat of Western Rock Lobster Larvae
12:00-12:15	Beckley, Lynnath	Influence of the anomalous Leeuwin Current on macro-zooplankton assemblages in the South-Eastern Indian Ocean
12:15-12:30	Hardman-Mountford, Nick	Ningaloo Nino and its influence on marine productivity in the Leeuwin Current

Tuesday 24 June, 14:00-15:30 Parallel session 2

Room D7

Time	Presenter	Title
14:00-14:15	Roberts, Michael	The role of the Agulhas Current (a western boundary current) in continental shelf production
14:15-14:30	Huggett, Jenny	Structuring of zooplankton communities by mesoscale eddies in the greater Agulhas Current system
14:30-14:45	Lamont, Tarron	Environmental influence on phytoplankton production during summer in a shelf region of the Agulhas ecosystem
14:45-15:00	Beckley, Lynnath	Boundary currents in the South Indian Ocean influence taxonomic diversity and distinctness of coastal fishes
15:00-15:15	Kidwai, Samina	Environmental conditions driving the zooplankton and fishery productivity across the Murray Ridge, Northwest Arabian Sea- winter monsoon 2010
15:15-15:30	Jones, Burton	Coupling of Biogeochemical Processes with Physical and Atmospheric Dynamics in the Red Sea

Poster presentation

Tuesday 24 June, 17:30 Poster Session 1

ID	Presenter	Title
E3.P1	Waite, Anya	Coastal particle injection into a forming mesoscale eddy in the Eastern Indian Ocean - impacts on oxygen and nitrogen dynamics

Influence of the anomalous Leeuwin Current on macro-zooplankton assemblages in the South-Eastern Indian Ocean

Beckley L.E., Holliday D., Sutton A. and Buchanan P.J.

The Leeuwin Current in the SE Indian Ocean is anomalous as it flows southward along the edge of the continental shelf of Western Australia. Although implicated in the distribution, abundance and recruitment of many species, few studies have actually investigated the biological oceanography of the current in situ. A multi-disciplinary examination of the Leeuwin Current system along the Western Australian continental shelf and adjacent ocean (22°–34°S) during the late austral autumn incorporated physics, nutrients, primary production and a depth-integrated, bongo-net survey of the macro-zooplankton. The temperature and salinity signatures of the Leeuwin Current experienced substantial modification as it flowed south; surface temperature decreased by ~5.25°C while surface salinity increased by ~0.72 psu.

Larval fishes were highly diverse comprising >200 taxa from 114 neritic and oceanic teleost families. A two-factor PERMANOVA indicated structuring of larval fish assemblages with latitude and across isobaths with a significant interaction term. MDS ordination of larval fish assemblages showed clustering of northern inner shelf stations (22°S - 28°S) with that of a developing meso-scale eddy at the 27°S oceanic station. Results from particle back-tracking indicated that, in the previous month, this eddy had strong connection with northern surface shelf waters. Larval fish assemblages at shelf break and oceanic stations throughout the study area had high similarity, and clustered with inner shelf stations south of 29°S indicative of geostrophic inflow, entrainment of Subtropical Surface Water and mixing of regional water masses from the continental shelf.

The krill assemblage of the Leeuwin Current system was diverse with 27 species identified, including nine species with tropical affinities. Isobath accounted for most of the assemblage structure, with lower species richness observed along the shelf. *Pseudeuphausia latifrons*, a tropical coastal species, was found at all stations emphasising the influence of alongshore and cross-shelf transport associated with the Leeuwin Current. Of the 19 chaetognath species identified from the Leeuwin Current system, six were new records for the region. Although there was a high degree of similarity (>75%) of the assemblage across the study area (with *Flaccisagitta enflata* numerically dominant), some chaetognath species displayed distinct tropical or temperate affinities. This resulted in a significant regional difference north and south of 28°S which coincided with the narrowing and intensification of the Leeuwin Current along the shelf edge. Phyllosoma larvae of the rock lobster, *Panulirus cygnus*, were also enumerated and found to occur only at the southern stations in the study area.

Overall, this study with concurrent physical and chemical oceanography, primary production and macro-zooplankton studies has demonstrated broad-scale advection of planktonic biota, both across the shelf, and alongshore, in the South-Eastern Indian Ocean.

Keywords: Fish larvae, krill, chaetognaths, phyllosoma

Oral presentation

Boundary currents in the South Indian Ocean influence taxonomic diversity and distinctness of coastal fishes

Beckley, L.E. and Clarke, K.R.

Southward dispersal of Indo-Pacific fishes in the Indian Ocean is strongly linked to poleward-flowing boundary currents off Australia and Africa. Coupled with early Gondwanan fragmentation, which largely defined the biogeography of temperate southern hemisphere taxa, the mixture of fishes around the rim of the South Indian Ocean provides an interesting case for broad-scale biodiversity analyses. Existing data-bases of fish distributions from South Africa and Western Australia were examined and well-defined biogeographic patterns were evident. When compared, the fishes of north-western Australia and north-eastern South Africa were most similar and maximum divergence was evident between the south coasts of Australia and Africa. Although, as expected, species diversity declined from north to south, the number of families of fishes across the latitudinal range was surprisingly consistent. The relatedness of fishes across the Indian Ocean was investigated using taxonomic distinctness measures (i.e. distances travelled in connecting every pair of species via a fixed set of levels in the hierarchical Linnean taxonomic tree). Average taxonomic distinctness ($\Delta+$) and variation in taxonomic distinctness ($\Delta+$), known theoretically to be insensitive to variation in sampling effort, both increased from north to south. Comparisons of these values with simulations of expected ranges under random sampling at different intensities indicated, for the south coasts of Australia and Africa, that taxonomic distinctness consistently exceeded the 95% upper limit of the simulations. This finding, of greater than expected taxonomic breadth, is largely unprecedented in the literature on observed patterns in taxonomic distinctness, emphasising the high, and unusual nature of, fish diversity in these regions.

Keywords: Biogeography, taxonomic breadth, Australia, South Africa

Oral presentation

Ningaloo Niño and its influence on marine productivity in the Leeuwin Current

Feng M. Presented by Hardman-Mountford N.

Ocean circulation off the Western Australia coast in the southeast Indian Ocean is dominated by the poleward-flowing Leeuwin Current. Interannual and decadal variability of the Leeuwin Current is to a large extent driven by tropical Pacific climate variability, such that the current is stronger during La Niña events and weaker during El Niño events. Interannual variability of productivity off the Western Australia coast is to a certain extent modulated by the Leeuwin Current and the associated thermocline depth and mesoscale eddies. Unprecedented warm sea surface temperature (SST) anomalies were observed off the west coast of Australia in February–March 2011, at the peak of “Ningaloo Niño”. Peak SST during a 2-week period were 5°C warmer than normal, causing widespread coral bleaching and fish kills. The extreme warming at the peak of the Ningaloo Niño was mostly driven by an unseasonable surge of the poleward-flowing Leeuwin Current in austral summer, which transported anomalously warm water southward along the coast. The unusual intensification of the Leeuwin Current was forced remotely by oceanic and atmospheric teleconnections associated with the extraordinary 2010-2011 La Niña. Satellite observations show that marine productivity was significantly reduced after the peak of the event, most likely due to deepened thermocline depth and reduced vertical mixing rate. The impacts of Ningaloo Niño and the reduction in marine productivity on fisheries recruitments have been assessed.

Keywords: marine heat wave

Oral presentation

Biogeochemical and Ecological Impacts of Boundary Currents in the Indian Ocean

Hood R., Beckley L. and Wiggert J.

Boundary currents mediate the fluxes of biogeochemical properties and planktonic ecosystems between major oceanic biomes and in so doing they also impact higher trophic level productivity, behavior and recruitment. In the northern Indian Ocean, several boundary current systems are seasonally reversing (e.g., the Somali Current, West and East India Coastal Currents, and the Java Current). These reversing surface currents are unique to monsoon-driven systems and although their transports are relatively small, they have profound biogeochemical and ecological impacts. For example, the nutrient stoichiometry of water upwelled along the coast of Oman during the Southwest Monsoon induces iron limitation and influences the species composition of the resulting blooms, which are transported hundreds of kilometers offshore in filaments and jets. And higher trophic level planktonic species (e.g., the copepod *Calanoides carinatus*) have evolved behavioral responses (vertical migration) to the seasonally changing conditions that appear to impact surface phytoplankton blooms and primary production. The southern currents (Agulhas and Leeuwin) both flow poleward throughout the year. The transport of the Leeuwin Current is also relatively small, but the poleward direction is unique among eastern boundary currents and it has many unusual biogeochemical and ecological impacts. For example, it sheds anomalous high chlorophyll, warm-core, downwelling eddies that transport productive diatom communities westward into open ocean waters. At higher trophic levels, variations in the Leeuwin transport and eddy generation impact rock lobster larvae recruitment and fate. In contrast, the transport of the Agulhas Current is huge, but it does not generate large seaward propagating eddies along the South African coast. On average, the Agulhas retroflects south of the continent to return eastward where it induces upwelling and enhances primary production. Most fish species in southern Africa (for example, the Southern African pilchard *Sardinops sagax*) have evolved highly selective behaviors and reproductive patterns to ensure that sufficient progeny are retained in nursery grounds along the coastline in the face of potent mechanisms for alongshore and offshore transport associated with the Agulhas Current.

Keywords: Somali Current, Agulhas Current, Leeuwin Current

Oral presentation

Structuring of zooplankton communities by mesoscale eddies in the greater Agulhas Current system

Huggett J., Lebourges-Dhaussy A. and Noyon M.

The Mozambique Channel (MC), located upstream from the Agulhas Current, is a region of high mesoscale variability. The general circulation is dominated by large anticyclonic eddies (300-350 km in diameter) that form near the narrows of the Channel at 16°S and propagate southwards along the African shelf edge at speeds of 3-6 km per day. These are often adjacent to smaller cyclonic eddies, which together form dipole eddy structures that strongly influence the production and transport of biological material by (1) upwelling within the cyclonic core, (2) extraction from the coastal region towards the oligotrophic mid-channel, and (3) entrainment around the eddy perimeters. Eddies also form at the southern tip of Madagascar, either moving northwards into the MC or westwards towards the African coast. To date we have conducted four studies of zooplankton abundance and community structure in mesoscale eddies within the MC (2007-2010), and one of a cyclonic eddy that formed off southern Madagascar (2013).

The four MC eddy studies revealed consistently greater mean biomass in the upper 200 m within cyclonic eddies and divergence areas (0.31 ml m⁻³) compared to anticyclonic eddies and frontal regions (0.20 ml m⁻³). The mesozooplankton community was strongly dominated by small copepods (~70-80% abundance) followed by appendicularians (10%), ostracods (8%) and chaetognaths (7%). The most abundant copepods were the Paracalanids, *Oncaea* spp., *Oithona* spp. and *Corycaeus* spp. Multivariate analysis revealed the communities were most strongly structured by depth, but classification (cyclonic/anticyclonic) was also important when mesoscale features were strongly developed. Multifrequency acoustic estimation of zooplankton biovolume in 2009 and 2010 reflected significantly higher biovolume in the cyclone than in the anticyclone of the well established dipole structure in 2009, but the opposite pattern in 2010 when the eddy field was less well defined. Vertical profiles indicated the smallest particles (<200 µm ESD) were concentrated in the upper 50 m, whereas the largest particles (2-6 mm ESD) were distributed throughout the sampled water column (200 m). Overall, zooplankton assemblages showed a high degree of homogeneity, with differences between mesoscale features largely due to varying abundances of similar species.

Preliminary findings suggest that the large (~300 km wide at the time of sampling) cyclonic eddy that originated off the southern coast of Madagascar ~2 months previously was characterised by a different copepod community compared to the MC eddies, comprising a greater proportion of Eucalanid copepods (*Rhincalanus* and *Subeucalanus* spp.). Mean biovolume in the eddy core (0.28 ml m⁻³) was similar to that found in the MC cyclonic eddies, whilst biovolume on the shelf of southern Madagascar was considerably higher (1.16 ml m⁻³). Sections through the eddy with a Laser-OPC (Optical Plankton Counter) indicated relatively high abundance of smaller particles (250-600 µm ESD) in the eddy core, and high abundance of both smaller and larger (600-1000 µm ESD) particles towards the eddy perimeter. Our results suggest mesoscale eddies play a fundamental role in shaping the regional pelagic ecosystem through the concentration, enhanced growth and redistribution of zooplankton communities.

Keywords: Zooplankton, Community structure, Eddies, Agulhas System
Oral presentation

Coupling of Biogeochemical Processes with Physical and Atmospheric Dynamics in the Red Sea

Jones B., Irigoien X., Stingl U., Stenchikov G. and Capone D.

The Red Sea is the major source of the salt flux into the intermediate water of the western Indian Ocean contributing the readily identifiable warm, salty, low oxygen intermediate water. However, the biogeochemistry of the Red Sea itself has received little attention until now. Recent and new efforts are contributing to understanding the interaction of physical, chemical and biological processes in the Red Sea and how these processes affect the characteristics of the Red Sea Water observed in the Arabian Sea and Indian Ocean. KAUST has begun a program to study the various processes that contribute to the biogeochemistry of the Red Sea. Several factors likely contribute to its overall productivity including inputs from Gulf of Aden, atmospheric dust inputs, and regional eddies that contribute to horizontal and vertical exchange processes. Using a combination of autonomous platforms, ship-based sampling, and experimental work KAUST is developing an integrated program to examine these processes. Initial results clearly show seasonal variations in the presence, intensity and type of eddies that drive the physical processes within the north central portion of the Red Sea.

Keywords: Red Sea, biogeochemistry, atmosphere, nutrients, eddies

Oral presentation

Northwest Arabian Sea- winter monsoon 2010

Kidwai S., Ahmed W., Mohsin Tabrez S., Fanning P., Mehmood K., Zia I., Khan M. W. and Ahmed N.

The Northwest Arabian Sea forms the Exclusive Economic Zone of Pakistan is one of the areas least studied from the region. In October-November 2010, during the Fishery Resource Appraisal Project of Pakistan (FRAPP, FAO/MFD), oceanographic observations were taken on board the Norwegian fishery survey vessel R.V. Dr. Fridtjof Nansen. The basic oceanographic observations included the temperature, salinity, Dissolved Oxygen (DO), nutrients, Chlorophyll a, phytoplankton and zooplankton. There were fifty four hydrocast and net stations, along eight transects off the Pakistan coast (shelf and deep water). The offshore of Pakistan (Indus Basin) is divided into two parts by the Murray Ridge, on the eastern side of the ridge, off the River Indus delta, the shelf is wider with a gentle slope and sandy cum muddy substrate, and a pronounced seasonal Oxygen Minimum Zone (OMZ) from 200-1500 m depth. In contrast, the west coast of Pakistan is seismically active area with a narrower shelf, steeper slope and rocky bottom. With the two contrasting conditions, the present study hypothesizes 1) the wide shelf and the mangroves of the River Indus delta contribute to the fishery productivity 2) the two contrasting transects east of the Murray Ridge (EMR) and west of the Murray Ridge (WMR) have different physical attributes that are observed in the temperature, salinity, fluorescence (proxy for Chlorophyll a) (CTD- SBE 911) and DO profiles (CTD and Multirosette) and reflect in the stratified zooplankton biomass (Multinet 5 nets, 200 um). Exploratory statistics and Multi variate analysis is applied to narrow the conditions into major components (EMR-shelf, interphase, deep; WMR- shelf, interphase,deep); compare the environmental conditions and explore relations with the zooplankton biomass. The link between the physical drivers with the higher trophic levels (zooplankton biomass and fishery productivity) is discussed.

Keywords: Arabian Sea, CTD, Zooplankton, fishery productivity

Oral presentation

Environmental influence on phytoplankton production during summer in a shelf region of the Agulhas ecosystem

Lamont T. and Barlow R.G.

During February 2010, time series studies of primary production (PP) and physiology were conducted at five selected sites on the KwaZulu-Natal (KZN) Bight of the Agulhas ecosystem as part of a programme to elucidate the influence of major physical driving forces and nutrient inputs on the structure and functioning of biological communities. These sites were located in the vicinity of the Durban lee eddy, in the mid-shelf region of the central part of the Bight, off the Tugela Mouth, and to the north and south of Richard's Bay. At 4 of the sites, phytoplankton biomass ranged from 0.10-1.44 mg m⁻³, and integrated PP ranged between 0.35 and 2.58 g C m⁻² d⁻¹. The highest biomass and PP, comparable to that observed in wind-driven upwelling systems, was associated with a diatom bloom observed at the mid-shelf site, varying between 0.26-4.27 mg m⁻³ and 7.22-9.89 g C m⁻² d⁻¹, respectively. Environmental conditions at each of the sites differed substantially and appeared to play an active role in initiating and controlling the development and distribution of phytoplankton biomass and production. Phytoplankton adaptation to varied environmental conditions was characterised by decreased α_B (initial slope) and an increase in PmB (maximum photosynthetic rate) with elevated temperatures. The converse (increased α_B and a decrease in PmB and E_k (light saturation)) was observed as irradiance levels declined. Generalised Additive Models (GAMs) revealed that irradiance, temperature, and biomass levels were the most important parameters influencing photosynthesis rates, and were able to account for 97.53 % of the deviance.

Keywords: Primary production, phytoplankton physiology, KwaZulu-Natal Bight, generalised additive models

Oral presentation

The role of the Agulhas Current (a western boundary current) in continental shelf production

Roberts R.

In this paper the role of the Agulhas Current (a western boundary current) as a major driver in the production of shelf chlorophyll is examined. Recent mooring array results show that the Agulhas Current is the most powerful western boundary current on the planet transporting some ~ 100 Sv with speeds of around 2.5 m s^{-1} . Most of its recognition comes from the critical role it plays in the global MOC with the transportation of salt and heat from the Indian Ocean into the Atlantic Ocean, as well as its influence on local climate, weather and rogue waves. To add to this however, there is now a growing body of research which demonstrates this western boundary current to also provide the energy to power up physical processes that result in the vertical movement of nutrients from depths of a few hundred meters (Indian Ocean Central Water) onto the adjacent continental shelf. This nutrient supply underpins much of the production in the shelf waters necessary to support local ecosystems. The processes (mechanisms) essentially fall into 2 categories: (1) fixed topographically induced and (2) dynamic (transitory). In the former case, the St Lucia upwelling cell, Durban eddy, Port St Johns eddy, and Port Alfred upwelling cell are the direct result of the swift Agulhas Current interacting with the shelf topography creating a zone of negative vorticity. The vertical movement of water in these divergent zones/lee-driven cyclonic eddies (i.e. nutrient pumps) is linked to the position and strength of the current relative to the slope. In the case of the dynamic (transitory) mechanisms, westward propagating deep sea eddies either directly interact with Agulhas Current producing a downstream propagating, single meander known as the Natal pulse, or displace the Current offshore to produce eddy-induced horizontal divergence and resultant slope upwelling. Interestingly, the Durban-eddy falls into both categories as once formed, it “breaks-away” from the subsurface bathymetry and then propagates downstream often in succession with a Natal pulse. The Natal pulse which occurs on average 4-5 times a year, comprises a slope trapped cyclone of some 100 km in diameter which similarly pulls nutrient-rich water up the continental slope enhancing production in the surface waters. The combination of the Natal and Durban break-away eddy produces vibrant production on the slope and shelf which moves along the east coast shelf. Given the size of the Agulhas Current and the unique smooth neighbouring slope/coastline relative to the other major western boundary currents — the Agulhas Current system serves as a natural laboratory to study boundary current-topography interactions.

Keywords: Agulhas Current, current-slope interactions, nutrients, production

Oral presentation

Living on the Edge of the Predator Pit: Nutrition and Oceanic Habitat of Western Rock Lobster Larvae

Waite A.M., Jeffs A., Beckley L.E., Thompson P.A., Raes E., Montoya J. and Landru J.

We show for the first time, the impact of planktonic food webs on the nutrition, growth and survival of larvae of the Western Rock Lobster while they undergo their 9-11 month planktonic phyllosoma phase in the Eastern Indian Ocean.

We present outcomes from two research voyages (2010-2011) investigating the planktonic prey fields, nutrition, and underlying food web supporting growth of lobster larvae. We present a new understanding of the feeding of late-stage phyllosoma in the wild, showing significant differences in larval nutrition between water masses, particularly between cold-core and warm-core eddies. We show that though phyllosoma have a preference for key zooplankton prey with specific nutritional attributes, the actual ocean prey field is sparse, limiting accumulation of nutritional reserves. This would limit their ability to metamorphose into the puerulus stage, cross the continental shelf, and settle to form the next generation of fishable adult lobsters. We hypothesize that remaining offshore is part of a strategy to avoid predation in the near-coastal “predator pit” (sensu Bakun, 2011).

The Western Rock Lobster is the most valuable single-species fishery in Australia, representing about 20% of the total value of Australia’s fisheries. Variability in settlement of puerulus stage and catch of adults has been shown to be highly correlated with the strength of the Leeuwin Current (in turn impacted by El Nino events) and westerly wind conditions. The below-average puerulus settlement for five years, including the two lowest on record, triggered a profound re-examination of mechanisms driving year class strength of larval settlement, since such fluctuations can pose a serious risk to a sustainable rock lobster industry. Our study directly addresses the hypothesis that productivity of the oceanic planktonic ecosystem offshore is a critical variable driving phyllosoma health and therefore recruitment success.

Keywords: rock lobster larvae, prey field, eddies

Oral presentation

Coastal particle injection into a forming mesoscale eddy in the Eastern Indian Ocean – impacts on oxygen and nitrogen dynamics

Waite A.M., Thompson P.A., Stemmann L.Feng, M. and Beckley, L.E.

Mesoscale eddies drive a significant component of cross-shelf transport important in the ecology of coastal ecosystems. The Leeuwin Current off Western Australia has a high kinetic energy in southwest WA which peaks and becomes unstable in the austral autumn triggering the formation of eddies. We hypothesized that eddy formation represented the major driver of cross-shelf transport during the autumn. We captured the dynamics of an evolving eddy in situ. Using a Lagrangian approach we traced water masses as they were incorporated into the eddy. ADCP profiles confirmed periodic offshore movement of ~ 2 Sv of shelf waters into the forming eddy from the adjacent shelf, carrying a load of coastally-sourced organic particles. This was followed by closing of the gap between inflow and outflow, such that the forming eddy became isolated from further direct input of coastal waters. Drifter tracks supported the anticyclonic surface flow peaking at the eddy perimeter and decreasing in velocity at the eddy centre. Oxygen and nutrient profiles suggested rapid remineralization of nitrate mid-depth in the isolated water mass as it rotates, with a total drawdown of oxygen of 3.6 mol m^{-2} to 350 m ($\sim 0.5 \text{ mol O}_2 \text{ m}^{-2} \text{ d}^{-1}$). We traced depletion of oxygen, and release of nitrate, within the rotating water mass on the timescale of ~ 1 week. This suggests an even more local source of nitrogen (N) that has recently been proposed (Thompson et al., 2011; Waite et al 2013) and suggests that both N supply and N turnover are extremely rapid in this system, such that nitrate is acting primarily as a regenerated nutrient rather than as a source of new nitrogen. Likely sources of C and N include coastal primary producers including seagrasses known to produce copious detritus which is prone to resuspension. We track the coastal particle injection as particle accumulations along density interfaces and progressive deepening of particle concentration peaks with time (lagrangian) and towards the eddy centre (eularian).

Keywords: mesoscale eddy, particle dynamics, nutrient fluxes

Poster presentation

The Influence of Upwelling and Boundary Current Dynamics on Biogeochemical Variability in the Eastern Indian Ocean

Wiggert J.

The eastern Indian Ocean (EIO) is subject to a wide variety of physical influences that combine to establish a complex underlying framework for the region's marine ecosystem. These influences include: 1) Wyrтки Jets in the equatorial wave guide that impinge on the Sumatra coast semiannually; 2) their subsequent northward and southward propagation as coastal Kelvin waves; 3) coastal upwelling along Sumatra and Java; 4) seasonal reversal of the Java Current and; 5) large magnitude freshwater inputs from the river systems around the Bay of Bengal and monsoon-linked runoff throughout the Indonesian Archipelago. Interannually, the physical processes and biogeochemical variability of the EIO are profoundly modulated by the Indian Ocean Dipole (IOD), though in situ quantification of the biogeochemical responses are sparse. In the absence of comprehensive field programs that provide needed realization of the seasonal and interannual variability, remote sensing platforms and observational arrays (e.g., ARGO network and RAMA array) can be employed for characterization at regional and seasonal to decadal scales. Through the combination of remote sensing data streams and ARGO data, the contrast in spatio-temporal biological response between the 1997/1998 and 2006/2007 IOD manifestations in the EIO has been explored previously. Here, moored time series from the RAMA array and sea surface salinity observations now available from the Aquarius-SACD platform are combined with remotely sensed ocean color, altimetry, SST and surface winds distributions to more comprehensively explore seasonal and interannual biophysical variability in the EIO.

Keywords: Indonesian Archipelago, Boundary Current, Wyrтки Jet

Oral presentation

Session F1: Climate-biogeochemistry interactions associated with open-ocean oxygen minimum zones

Oral Presentations

Thursday 26 June, 14:00-15:30 Parallel session 7

Room D4

Time	Presenter	Title
14:00-14:15	Gruber, Nicolas	The differential impacts of upwelling intensification on oxygen in Eastern Boundary Upwelling Systems
14:15-14:30	Montes, Ivonne	High-resolution modeling of the Eastern Tropical Pacific Oxygen Minimum Zone: Sensitivity to the tropical oceanic circulation
14:30-14:45	Garçon, Véronique	Inference of super-resolution ocean pCO ₂ and air-sea CO ₂ fluxes from non-linear and multiscale processing methods
14:45-15:00	Stramma, Lothar	Circulation, eddies and trends in the oxygen minimum zone off Peru
15:00-15:15	Miquel, Juan-Carlos	Downward carbon flux in the Peruvian OMZ region
15:15-15:30	Shigemitsu, Masahito	Climate-driven variability and anthropogenic trend of oceanic suboxia

Friday 27 June, 10:30-12:00 Parallel session 8

Room D4

Time	Presenter	Title
10:30-10:45	Croot, Peter	Redox controls on the Biogeochemical cycling of Iodine in the Open Ocean - potential impacts of expanding Oxygen Minimum Zones on the air/sea flux of Iodine with implications for climate.
10:45-11:00	Färber Lorda, Jaime	Confirmation of the Habitat Compression Hypothesis and euphausiids metabolic response to low oxygen conditions in the Oxygen Minimum Zone of the Eastern Tropical Pacific
11:00-11:15	Bianchi, Daniele	Interactions between oxygen minimum zones and animals - the role of diel vertical migrations
11:15-11:30	Schmidt, Martin	Is Zooplankton able to stabilize the oxygen content of oceanic oxygen minimum zones?
11:30-11:45	Eggert, Anja	Physical-biological controlling of the oxygen budget on the Namibian shelf
11:45-12:00	Dadou, Isabelle	The Benguela Upwelling System within an Oxygen Minimum Zone: Potential changes over a warmer climate

Interactions between oxygen minimum zones and animals - the role of diel vertical migrations

Bianchi B.

Oxygen minimum zones (OMZ) remove fixed-N from the ocean, limit the range of marine species, and are predicted to expand under global warming. Many open questions remain on the physical and biogeochemical interactions that control OMZ and drive their variability. In OMZ, oxygen deficits are maintained by a range of biological processes, among which degradation of organic particles by bacteria is generally considered the dominant one. Mesozooplankton and micronekton, including small pelagic fish, intercept and respire a significant fraction of the primary production - in an amount comparable to particle remineralization at depth, but their contribution to ocean chemistry and oxygen cycling has received little attention. Contrary to microbes, animals actively move along vertical distances of several hundred meters, in what are known as diel vertical migrations, providing a direct connection between the surface and the mesopelagic zone, where OMZ are located. Here we use observations and models to study the connection between animals and OMZ. Using a global acoustic dataset we describe the association of OMZ and diel vertical migrations, and show that vertically migrating animals gather in the upper margins of OMZ, where they may find shelter from predators whose range is limited by oxygen. With the help of a hierarchy of ocean biogeochemistry models, we show that at the depths where migrators congregate, animal respiration and excretion are large enough to impact the cycling of oxygen itself, and, in oxygen deficient waters, the pathways of fixed-N removal.

Keywords: OMZ, DVM, zooplankton, micronekton

Oral presentation

Redox controls on the Biogeochemical cycling of Iodine in the Open Ocean – potential impacts of expanding Oxygen Minimum Zones on the air/sea flux of Iodine with implications for climate.

Croot P.

Iodine is a pseudo conservative element in seawater and is present predominantly as the inorganic redox species, iodide (I^-) or Iodate (IO_3^-), with only minor amounts of dissolved organic iodine (DOI) species. Volatile DOI species (e.g. CH_3I) are climatically important trace species however as they are a source of Iodine to the atmosphere from the ocean and can subsequently be oxidized to form new aerosol particles. In oxygenated seawater, IO_3^- is the thermodynamically favored species, though in the euphotic zone the reduction of IO_3^- to I^- is relatively facile through either photoreduction or phytoplankton activity. As the O_2 dependent back oxidation to IO_3^- is a considerably slower reaction it results in appreciable I^- in surface waters and in the core of an Oxygen Minimum Zone (OMZ). Recent data indicates if the core of an OMZ drops below an apparent threshold of $\sim 10 \mu M O_2$ the equilibrium shifts to almost exclusively I^- . Intermediate species produced during the redox cycling of iodine between IO_3^- and I^- include the gaseous species HOI and I_2 which can react with organic matter to produce DOI. In OMZs O_2 and other ROS related species act as a redox switch between IO_3^- and I^- resulting in cycling between these species in the oxycline. Furthermore the high iodide concentrations in surface waters may act as a principal constraint on atmospheric O_3 deposition. Expanding OMZs will most likely result in an increase in the I^- concentrations across the ocean and potentially increase the range and flux of Iodine from the open ocean as a consequence. This presentation will examine the current state of knowledge on iodine speciation in seawater and present new open ocean data from the equatorial Pacific and the Eastern Tropical South Pacific.

Keywords: OMZ, iodine redox biogeochemistry, climate change

Oral presentation

The Benguela Upwelling System within an Oxygen Minimum Zone: Potential changes over a warmer climate

Dadou I., Machu E., Le Vu B., Goubanova K. and Garçon V.

Among the different Eastern Boundary Upwelling Systems, the Benguela upwelling system (BUS) presents one of the highest primary productions of all EBUS with an Oxygen Minimum Zone (OMZ) in its northern part.

We investigate the impact of different drivers on production and biomass in the BUS under future potential climate change (scenario A1B2, 2080-2100: A1B(2080-2100)) compared to present period (PD(1980-2000)). To this end, a 3-D regional high resolution coupled physical-biogeochemical model (ROMS/BioEBUS already validated for the BUS) was forced by global climate simulations with downscaled winds from the IPSLCM4 model.

The results show that in the BUS this forcing corresponds to a mean SST increase of 1.4°C over the whole domain and is associated with a decrease of alongshore winds magnitude (-10% in its northern part) and of oxygen concentrations (-20-30 mmolO₂.m⁻³ in its northern part). These climate drivers influence the ecosystem of the BUS with a subsequent decrease of primary production (-0.12; fractional change = [(A1B(2080-2100) / PD(1980-2000)) -1]; (-1 to 0: decrease, positive values: increase)), phytoplankton (-0.148) and zooplankton (-0.126) biomasses over the whole domain. However an unexpected ecological niche with increased production and plankton biomass could develop in the northern part of the BUS and along the coast, associated with the increase of temperature, stratification and decrease of the winds.

Keywords: OMZ, Benguela, Upwelling, climate change

Oral presentation

Physical-biological controlling of the oxygen budget on the Namibian shelf

Eggert A., Muller A.A., Mohrholtz V. and Schmidt M.

Physical and biological processes determine the distribution of dissolved oxygen in the ocean. We analysed simulation results of a fully coupled hydrodynamic and biogeochemical ecosystem model of the northern Benguela Upwelling System (BUS, 16-28°S) to identify the relevant source and sink terms governing the regional oxygen budget. Based on an 8 year climatology (2000-2008) we present the oxygen budget for the Namibian shelf. In order to investigate spatial heterogeneity caused by the great variability in the bathymetry of the continental margin, we divided the shelf into four domains of equal latitudinal dimensions. This offered the opportunity to specifically compare the dynamics of the oxygen budget of the two major upwelling cells (Cape Frio and Lüderitz) with those of the two central regions off Namibia. Near-surface water typically has high dissolved oxygen concentration due to recent exchange with the atmosphere and oxygen evolution in the euphotic zone. Both coastal upwelling and specifically the subsurface transport of low oxygen water in the pole-ward undercurrent (PUC) along the Namibian coast determine the expansion of shelf hypoxia at intermediate water depth. The oxygen drawdown by mineralisation of sinking organic matter maintains steep oxygen gradients in the water column. Most importantly, the model also comprises nutrient cycling in the bottom sediment and distinguishes between thin oxic and thick anoxic sediments, the latter being covered by mats of large sulfur bacteria. This implementation turned out to be important as these benthic bacteria keep the redoxcline confined to the sediment and minimise the release of hydrogen sulfide into the water column. The model results show that the PUC imprints a significant seasonal signal on the local biogeochemical oxygen drawdown. In austral summer, the PUC replaces the well ventilated water at the shelf edge with oxygen poor water, but also supplies some oxygen to the otherwise anoxic bottom layer at the inner shelf. Predicted changes in wind-driven upwelling will affect the subtle balance of the physical and biological processes controlling of the oxygen budget on the Namibian shelf with severe impacts on the marine ecosystem.

Keywords: upwelling ecosystem, Benguela, oxygen minimum zone

Oral presentation

Confirmation of the Habitat Compression Hypothesis and euphausiids metabolic response to low oxygen conditions in the Oxygen Minimum Zone of the Eastern Tropical Pacific

Farber Lorda J., Farber B., Beier E., Godinez V., Herrera I., Yebra L. and Hernandez S.

Samples obtained with a MOCNESS net were used to study zooplankton's vertical distribution. Along the two transects studied hydrography showed in the north (transect B) a less stratified structure and deeper oxygen minimum, while the southern transect (transect D) was more stratified with a shallower oxygen minimum. All taxonomic groups, except euphausiids, showed vertical migration, only within the oxygenated layer, in the first 100 m. Euphausiids do migrate at least in the sampled depth range (0-500 m), well within the Oxygen Minimum Zone. This confirms the Habitat Compression Hypothesis with a significant number of samples obtained in the same conditions. The dominant euphausiid species *Euphausia distinguenda*'s metabolic response was studied. Being a vertical migrator, during the night, they showed high respiration (ETS, Electron Transport System activity) and growth (AARS Aminoacyl-tRNA synthetase activity) rate, in well oxygenated, near surface waters, and low values during the day, in deep waters. A positive relationship was found between both enzymes activities and oxygen, and a negative relationship between gut fluorescence and oxygen concentrations. A gyre present in the area influenced the productivity of the sampled area, POM (protein+carbohydrates+ lipids) was relatively high in both transects, more in the near shelf zone. The pH in the area was slightly higher in the open ocean California Current influenced zone of transect B, possibly, pH and oxygen have a synergistic effect on zooplankton vertical distribution.

Keywords: Oxygen minimum, zooplankton vertical migration

Oral presentation

Inference of super-resolution ocean pCO₂ and air-sea CO₂ fluxes from non-linear and multiscale processing methods

Garçon V., Sudre J., Hernandez I., Dewitte B., Illig S., Dadou I. and Paulmier A.

In recent years the role of submesoscale activity is emerging as being more and more important to understand global ocean properties, for instance, for accurately estimating the sources and sinks of Greenhouse Gases (GHGs) at the air-sea interface. The scarcity of oceanographic cruises and the lack of available satellite products for GHG concentrations at high resolution prevent from obtaining a global assessment of their spatial variability at small scales. In this work we develop a novel method to reconstruct maps of CO₂ fluxes at super resolution (4km) using SST and ocean colour data at this resolution, and CarbonTracker CO₂ fluxes data at low resolution (110 km). The responsible process for propagating the information between scales is related to cascading properties and multiscale organization, typical of fully developed turbulence. The methodology, based on the Microcanonical Multifractal Formalism, makes use, from the knowledge of singularity exponents, of the optimal wavelet for the determination of the energy injection mechanism between scales. We perform a validation analysis of the results of our algorithm using pCO₂ ocean data from in-situ measurements in the upwelling region off Namibia.

Keywords: GHG, multiscale cascading, remotesensing, Namibia upwelling

Oral presentation

The differential impacts of upwelling intensification on oxygen in Eastern Boundary Upwelling Systems

Gruber N., Lachkar Z. and Franco-Novela A.C.

The increase in the land-ocean contrast expected from future global warming likely will lead to an intensification of upwelling in most Eastern Boundary Upwelling Systems. This tends to cause not only an increase in primary production, but also an enhanced downward transport of organic matter, inducing an increased oxygen demand at depth. Thus, it is reasonable to expect that upwelling intensification will reduce the oxygen concentration in the upper ocean of these systems, potentially pushing some of these systems into serious hypoxia. However, the analyses of our idealized upwelling intensification simulations for the Canary, California, and Humboldt Current Systems (CS) using regional setups of the Regional Oceanic Modeling System (ROMS) revealed strongly diverging trends. While upwelling intensification induced by doubling the winds stress causes a sharp decrease in oxygen in the California CS, the same forcing causes O_2 to increase in the Canary and Humboldt CSs. This differential response is a consequence of the fundamentally different factors that control the oxygen concentration in the thermoclines of these three systems. In the case of the California CS, oxygen in the thermocline is primarily controlled by the large-scale advection of low oxygen waters from the eastern South Pacific Oxygen Minimum zone, while in the case of the Canary CS, it is the balance between mixing and export production that sets the oxygen levels. Enhanced upwelling leads in the California CS to an increased upward advection of the low oxygen levels from below, explaining the lowering of O_2 there. In contrast, in the Canary CS, upwelling causes a stronger offshore transport of nearshore waters, thereby moving a much larger fraction of the organic matter off to the open ocean, causing a reduced oxygen demand in the nearshore region, explaining the increase in oxygen. In the Humboldt CS, it also appears that it is primarily the large-scale supply that governs the O_2 in the thermocline, but there, the increase in upwelling in response to the doubling of the windstress induces a stronger supply of high oxygen waters to the nearshore. Our simulations thus reveal that despite many similarities between the different EBUS, their response to upwelling intensification can differ substantially, requiring an approach that takes the local aspects explicitly into consideration.

Keywords: EBUS, oxygen

Oral presentation

Downward carbon flux in the Peruvian OMZ region

Miquel J.C., Gasser B., Neira K., Reichert P. and Scholten J.

The quantification of carbon flux and understanding the processes involved in the production of biogenic matter that settles in the water column are of paramount importance in studying biogeochemical cycles in the oceans, carbon sequestration and the health of marine ecosystems. Traditionally, the measurement of particle and carbon fluxes has been realized by collecting sinking particles with sediment traps drifting in the water column or anchored at the ocean's bottom. An alternative and complementary method consists in estimating the carbon flux indirectly by measuring natural radioisotopes, in particular U-238 and its direct decay product, Th-234. The disequilibrium between this pair of radionuclides in the productive surface waters is used to estimate the flux of carbon and other elements associated with particles.

As part of the science project, SFB 754-Germany, we participated in a scientific mission aboard the German research vessel, "Meteor", off the Peruvian coast in January and February 2013. The sampling zone focused on the oxygen minimum zone around 12° and 13°S, and our task consisted in the measurement of dissolved and particulate Th²³⁴ as well as of particulate organic carbon, in order to calculate the downward carbon flux in this highly complex and dynamic area. Results obtained will be presented and compared to data obtained during a previous campaign, which took place off the Chilean coast around latitudes 33-35°S. These results confirm the high biological activity known from upwelling zones, which yields considerable carbon fluxes reaching deep waters.

Keywords: carbon flux, radioisotopes, OMZ, South-East Pacific

Oral presentation

High-resolution modeling of the Eastern Tropical Pacific Oxygen Minimum Zone: Sensitivity to the tropical oceanic circulation

Montes I., Dewitte B., Gutknecht E., Paulmier A., Dadou I., Oschlies A. and Garçon V.

The connection between the equatorial mean circulation and the oxygen minimum zone (OMZ) in the Eastern Tropical Pacific is investigated through sensitivity experiments with a high-resolution coupled physical-biogeochemical model. The model is first validated with observations to assess its performance in simulating a realistic vertical and horizontal oxygen distribution. Two sets of climatological open boundary conditions (OBCs, for the physical variables) which differ slightly on the intensity and vertical structure of the Equatorial Current System (ECS) are shown to lead to contrasted characteristics of the simulated OMZ by the regional model. Through a Lagrangian approach, the oxygen transport between the ECS and Peru-Chile Undercurrent is also evaluated, emphasizing on the main branches connecting both current systems. The experiments allow identifying that the secondary Tsuchiya jet (secondary Southern Subsurface Countercurrent, sSSCC) is a key feature of the sensitivity of the OMZ to the equatorial circulation. A further investigation is followed to study the differences in OMZ dynamics due to the different background conditions (both O₂ and mean circulation) between the two simulations, which is based on an explicit O₂ budget. The main results showed that there is a significantly different balance between physical and biogeochemical processes within the energetic coastal current system between the two simulations, illustrating the large sensitivity of the OMZ dynamics to the open boundary conditions.

Keywords: Oxygen Minimum Zone, Equatorial Current System

Oral presentation

Is Zooplankton able to stabilize the oxygen content of oceanic oxygen minimum zones?

Schmidt M., Auel H., Buchholz F., Eggert A., Mohrholz V. and Werner T.

The oxygen concentration within the oxygen minimum zone in the Angola Gyre is almost constant over long times, where ventilation balances oxygen consumption by mineralization of organic material. A simple physical explanation is that the turbulent oxygen flux is governed by Fick's law, where the oxygen flux is proportional to the oxygen concentration gradient. Here, we discuss an alternative feedback mechanism from the zooplankton respiration towards ambient oxygen concentration by vertical migration of zooplankton. This idea is based on model results from a coupled biogeochemical model, respiration, hypoxia tolerance and acoustic measurements showing in how far zooplankton avoids low oxygen waters. Zooplankton vertical migration implies considerable transport of organic matter. Zooplankton respiration as well as nitrification of excreted ammonium is an essential sink of oxygen. If zooplankton is avoiding oxygen exhausted water bodies, oxygen consumption from respiration and nitrification is reduced considerably there. For the biogeochemical model considered this feedback is an essential component to produce a realistic oxygen minimum zone, whereas a simple bulk zooplankton significantly overestimates its extent and apparent oxygen utilization.

Keywords: oxygen minimum, zooplankton, ecosystem model

Oral presentation

Climate-driven variability and anthropogenic trend of oceanic suboxia

Shigemitsu M., Yamamoto A., Oka A. and Yamanaka Y.

Variability of oceanic suboxic water volume is critical for aerobic organisms. Several climate models consistently predict the decreasing oceanic oxygen inventory from the second half of the 20th to the 21st centuries. However, the projections about how the volume of suboxia changes in the future are not consistent with each other. In this study, we investigated the factors controlling the variability of suboxic water volume in the Eastern Tropical Pacific where the largest suboxic zone exists in the ocean. Hindcast (from years 1850 to 2005) and forecast (from years 2006 to 2100) experiments with an offline global ocean biogeochemical model were performed by using outputs of physical variable by the Earth System Model, MIROC-ESM, under the RCP8.5 scenario. The model results illustrated that the suboxic water volume in the Eastern Tropical Pacific remains relatively stable with decadal fluctuations from years 1850 to 1950, rapidly increases from years 1950 to 2000, and gradually declines from years 2000 to 2100. The suboxic water volume at the end of the 21st century did not come back to the values seen in year 1950. Available observations are consistent with the change of oxygen concentration there from years 1950 to 2000. The simulated decadal variability of suboxic water volume was inversely correlated with the modeled temporal fluctuation of the El Niño-Southern Oscillation-like decadal variability (DENSIO) from years 1850 to 1950. The regional oxygen budget in the control volume (defined as the modeled maximum volume of suboxic water) reveals that the physically- and biologically-driven oxygen changes vary almost together, they are positively correlated with the DENSIO from years 1850 to 1950, and the subtle balance between both changes tends to generate the inverse correlation of suboxic water volume with the DENSIO during the period. The DENSIO continue to increase from years 1950 to 2100. During this period, the climate-driven variability of suboxic water volume mentioned above is masked by the anthropogenic trend. The physically- and biologically-driven oxygen changes in the control volume tend to together decrease during years 1950 to 2000 and increase during the 21st century. The subtle balance between them again tends to generate the negative time rate of change of oxygen in the volume from years 1950 to 2000 and the positive rate during the 21st century, leading to the simulated time evolution of suboxia. The initial oxygen concentration in the control volume at the time when the suboxia begins to expand (year 1950) or contract (year 2000) appears to be crucial for determining the time evolution of suboxia. That is because biologically-driven change of oxygen is parameterized to vary depending on surrounding oxygen concentration, and response of the same amount of organic matter flux from the above ocean to the suboxic zone is different from each other.

Keywords: earth system model, hindcast, forecast

Oral presentation

Circulation, eddies and trends in the oxygen minimum zone off Peru

Stramma L., Czeschel R., Schwarzkopf F.U., Fischer T. and Weller R.A.

A strong oxygen minimum zone (OMZ) is located in the tropical eastern South Pacific off Peru. Recent observations show that on the equatorial side of the OMZ zonal current bands dominate the oxygen budget, while on the poleward side eddies contribute considerably. The circulation in the OMZ off Peru is investigated based on cruises in January/February 2009 and November/December 2012 and is compared to model results. A hindcast experiment for the period 1948 to 2009, forced by atmospheric reanalysis products, merged with satellite data (CORE v.2) of the 0.1° high-resolution model of the Tropical Pacific (TROPACO1) is used. The modelled circulation is subject to strong interannual variability and agrees remarkably well with observations, when comparing them at the same point in time. In the equatorial channel oxygen-rich water is transported to the eastern Pacific by the zonal equatorial current bands. Near the American continent this water is transported poleward by subsurface currents near the shelf. In many regions of the OMZ the circulation is sluggish. Hydrographic and biogeochemical measurements in eddies as well as float tracks show that eddies transport anomalous water masses and biogeochemical properties offshore. Available oxygen deficits in anticyclonic eddies compared to the surrounding water are about 10×10^{16} micromol. From repeat hydrographic and historical data trends in oxygen can be determined. In most tropical regions oxygen has decreased in the last decades. However, in the eastern tropical Pacific Ocean oxygen trends are not everywhere negative, there are also regions with increasing oxygen. Typical oxygen trends for the last few decades in the upper ocean range from -0.5 to $+0.4$ micromol $\text{kg}^{-1} \text{yr}^{-1}$.

Keywords: oxygen deficits, oxygen trends, supply, eddies

Oral presentation

Session F2: Regional responses to climatic and non-climatic drivers in a high-CO₂ ocean

Oral presentations

Wednesday 25 June, 11:00-12:30

Chair: Patrizia Ziveri

Room D3

Time	Presenter	Title
11:00-11:05	Ziveri, Patrizia	Introduction to the session
11:05-11:20	Maugendre, Laure	Effect of ocean warming and acidification on a plankton community in the NW Mediterranean Sea
11:20-11:35	Zervoudaki, Sultana	Effects of raised CO ₂ and Temperature on composition, production and feeding behavior of marine copepods during mesocosm experiments in the Mediterranean Sea.
11:35-11:50	Manno, Clara	Pteropod race for life: behavioural responses to anthropogenic climate change
11:50-12:05	Bouquet, Jean-Marie	Response of the pelagic, gelatinous appendicularian <i>Oikopleura dioica</i> to ocean warming and acidification
12:05-12:20	Segovia, Maria	Interactive effects of increased CO ₂ levels and iron availability on the marine pelagic food web during a mesocosm experiment
12:20-12:30	All	General Discussion

Wednesday 25 June, 14:00-15:30

Chair: Jean-Pierre Gattuso

Room D3

Time	Presenter	Title
14:00-14:15	Rees, Andy	Acidification of the Marine Nitrogen Cycle
14:15-14:30	Georgian, Samuel	Ocean acidification in the deep Gulf of Mexico: ongoing field and experimental investigation of the potential effects of acidified bottom water on cold-water corals
14:30-14:45	Steckbauer, Alexandra	Metabolic responses different Mediterranean invertebrate species to high CO ₂ and low O ₂
14:45-15:00	Kim, Kyungsu	The combined effects of elevated CO ₂ and temperature on the physiological conditions of olive flounder larvae, <i>Paralichthys olivaceus</i>
15:00-15:15	Endres, Sonja	Do bacteria thrive when the ocean acidifies? Results from an off-shore mesocosm study
15:15 -15:30	All	General Discussion

Wednesday 25 June, 16:00 – 17:30

Chair: Patrizia Ziveri

Room D3

Time	Presenter	Title
16:00-16:15	Riebesell, Ulf	Plankton community responses to ocean acidification and their impacts on biogeochemical cycling: results from mesocosm studies covering a range of environmental conditions
16:15-16:30	Richards, Russell	Ocean acidification - challenges for shell fish aquaculture
16:30-16:45	Giannakourou, Antonia	The combined effect of pCO ₂ and temperature increase on bacterioplankton in the Eastern Mediterranean.
16:45-17:00	Solidoro, Cosimo	Modelling the state of the Mediterranean Sea under contemporary and future climate
17:00-17:15	Artioli, Yuri	A high-CO ₂ North Western European shelf: interactions between ocean acidification, climate change and eutrophication
17:15 -17:30		Final Discussion, Remarks, Questions

Poster Presentations

Wednesday 25 June, 17:30, Poster Session 2

ID	Presenter	Title
F2.P1	Ziveri, Patrizia	Biodiversity of coccolithophores and <i>Emiliana huxleyi</i> calcite mass from surface sediments of the Mediterranean Sea in a changing climate
F2.P2	Orr, James	An International Coordination Centre promoting cooperative actions that address ocean acidification
F2.P3	Iñiguez Moreno, Concepcion	Effect of increased CO ₂ and dissolved iron on primary productivity and inorganic carbon uptake during a bloom of the coccolithophore <i>Emiliana huxleyi</i>
F2.P4	Lorenzo, María Del Rosario	The Effects of Ocean Acidification and Siderophore Additions on Trace-Metal Dynamics during an <i>Emiliana Huxleyi</i> -Dominated Bloom in a Coastal Mesocosm Experiment
F2.P5	Shaltout, Nayrah	Impact of Ocean Acidification on the Growth and Ultrastructure of Non-calcifying Marine Diatom (<i>Chaetoceros gracilis</i> F. Schütt)
F2.P6	Vidussi, Francesca	Effects of acidification and warming on a coastal Mediterranean plankton food web: the WARMACIDWEB mesocosm experiment
F2.P7	Ziveri, Patrizia	Mediterranean Sea acidification in a changing climate: the European MedSeA project
F2.P8	Peck, Victoria	Ocean acidification exposes scars from a violent past
F2.P9	Giani, Michele	Carbonate system variability and buffer capacity in a Mediterranean estuarine area (Gulf of Trieste, Northern Adriatic Sea)

A high-CO₂ North Western European shelf: interactions between ocean acidification, climate change and eutrophication

Artoli Y., Blackford J.C., Butenschön M., Wakelin S.L. and Holt J.T.

Modelling Ocean Acidification (OA) in marginal seas is a challenge: carbonate chemistry is driven not only by the air-sea CO₂ fluxes but also by river discharges, high biological activity and benthic-pelagic interactions. All these processes, and their relative change in the future, are responsible for modulating the main signal due to the increase of atmospheric pCO₂.

We applied a suite of coupled physical-biogeochemical models to simulate OA in the North Western European shelf both in the recent past and in the future (up to the year 2100) using different climate (IPCC AR4-A1B and AR5-RCP8.5, with or without OA feedbacks on primary production) and anthropogenic (nutrient loads) scenarios. Models highlighted high temporal and spatial variability in the OA signal, due to physical (e.g., higher warming in the shelf) or biological (e.g., high primary production) features.

Comparing outputs from different scenarios, it has been possible to investigate the relative importance of the different drivers on marine system functionality. In the short timescale (~2030) reduction in nutrient loads could decrease pH in coastal areas as much as OA. On a longer timescale (~2100), the potential increase of primary production due to OA could both mitigate or exacerbate (depending on the area) the impact of climate change on phytoplankton and zooplankton production, with ensuing effects on community composition and phenology.

Keywords: Ocean Acidification; impacts; climate change; eutrophication

Oral presentation

Response of the pelagic, gelatinous appendicularian *Oikopleura dioica* to ocean warming and acidification

Bouquet J.M., Troedsson C., Parida M., Reeve M., Dupont S., Novac A., Sandnes Skaar K., Massart W., Manak J.R. and Thompson E.M.

It is now widely accepted that the increase of atmospheric CO₂ levels from anthropogenic emissions is resulting in a global temperature elevation and acidification of the world's oceans (ocean acidification, OA). The oceans presently absorb one-fourth of the CO₂ emitted in the atmosphere. Furthermore, atmospheric levels are projected to double by the end of the century following current emission trajectory. Currently our understanding of the effects of elevated pCO₂ is still rudimentary, but increasing evidence demonstrates that OA can impact survival, growth, development and physiology of marine organisms and profoundly alter the complex balance of marine ecosystems. This is important because changes in primary production may drastically affect ecosystem functioning by altering trophic pathways and the biogeochemical quality of organic material in food webs. Effects on marine pelagic processes are hypothesized to include a shift in plankton communities towards smaller cells, reduced carbon export rates and an increased role of gelatinous zooplankton in carbon cycling. One major representative of gelatinous zooplankton communities are the urochordate appendicularians. Appendicularians are circum global zooplankton, considered to be the second most abundant mesozooplankton, after copepods, in many marine ecosystems. Through the production of an extracellular filter-feeding house, appendicularians can shortcut the classical marine food web by feeding efficiently on the submicron fraction. The houses are repetitively secreted and frequently discarded throughout the life cycle. This material, generally loaded with food particles and fecal pellets contributes to a major fraction of marine snow and thereby, to global vertical carbon flux. In the context of current prediction models (~ 0.4 pH units by elevating CO₂ to 3x modern levels and warming 3°C), the aim of this project is to study both acute and adaptive impact of OA and climate change on the urochordate *Oikopleura dioica* at laboratory and mesocosm scales, as well as to understand the effect of these global changes on planktonic communities and pelagic food webs. Our results suggests that OA had no impact on *O. dioica*'s development (maturation and reproduction success, survival, growth), but significantly increased production of mature oocytes and therefore increased population size in the following generation. To try to obtain more detailed molecular insight into the effects of these environmental changes, whole-transcriptome assessment of spawned oocytes was performed by RNA-seq. Preliminary results of maternally stocked mRNAs in oocytes indicate differential gene expression during oogenesis in response to principally temperature, but also acidification manipulations.

Keywords: Zooplankton, climate change, anthropogenic CO₂, pelagic food webs, microcosm, mesocosm

Oral presentation

Do bacteria thrive when the ocean acidifies? Results from an off-shore mesocosm study

Endres S., Galgani L., Riebesell U., Schulz K.G. and Engel A.

Marine bacteria are the main consumers of the freshly produced organic matter. In order to meet their carbon demand, bacteria release hydrolytic extracellular enzymes that break down large polymers into small usable subunits. Accordingly, rates of enzymatic hydrolysis have a high potential to affect bacterial organic matter recycling and carbon turnover in the ocean. Many of these enzymatic processes were shown to be pH sensitive in previous studies. Due to the continuous rise in atmospheric CO₂ concentration, seawater pH is presently decreasing at a rate unprecedented during the last 300 million years with so-far unknown consequences for microbial physiology, organic matter cycling and marine biogeochemistry.

We studied the effects of elevated seawater pCO₂ on a natural plankton community during a large-scale mesocosm study in a Norwegian fjord. Nine 25m-long Kiel Off-Shore Mesocosms for Future Ocean Simulations (KOSMOS) were adjusted to different pCO₂ levels ranging from ca. 280 to 3000 µatm by stepwise addition of CO₂ saturated seawater. After CO₂ addition, samples were taken every second day for 34 days. The first phytoplankton bloom developed around day 5. On day 14, inorganic nutrients were added to the enclosed, nutrient-poor waters to stimulate a second phytoplankton bloom, which occurred around day 20.

Our results indicate that marine bacteria benefit directly and indirectly from decreasing seawater pH. During both phytoplankton blooms, more transparent exopolymer particles were formed in the high pCO₂ mesocosms. The total and cell-specific activities of the protein-degrading enzyme leucine aminopeptidase were elevated under low pH conditions. The combination of enhanced enzymatic hydrolysis of organic matter and increased availability of gel particles as substrate supported higher bacterial abundance in the high pCO₂ treatments. We conclude that ocean acidification has the potential to stimulate the bacterial community and facilitate the microbial recycling of freshly produced organic matter, thus strengthening the role of the microbial loop in the surface ocean.

Keywords: marine bacteria, ocean acidification, enzymes, TEP

Oral presentation

Ocean acidification in the deep Gulf of Mexico: ongoing field and experimental investigation of the potential effects of acidified bottom water on cold-water corals

Georgian S., Lunden J., Cordes E.

Anthropogenic disturbance of marine environments is increasing globally at an unprecedented rate and scale. One of the most immediate and profound threats is ocean acidification, the reduction in seawater pH as a result of atmospheric CO₂ emissions. Acidification reduces the saturation state (Ω) of the calcium carbonate minerals used by many marine invertebrates to calcify skeletal material. As saturation states decline, deep-sea ecosystems will be the first exposed to undersaturated waters because of their proximity to the saturation horizon. Among the most vulnerable groups are cold-water corals, which precipitate extensive skeletal structures that fill vital ecological roles by creating complex habitat, and have considerable impacts on carbon cycling and biodiversity in the deep-sea. *Lophelia pertusa* is one of the most abundant and widely distributed cold-water corals. It forms extensive reef structures that may cover areas on the order of several kilometers squared and mounds that can be hundreds of meters in height. These structures have been characterized as biodiversity hotspots that provide vital habitat for over 1,300 associated species, including several commercially important fish. In 2010, we collected the first carbonate data for the deep Gulf of Mexico, and demonstrated that *L. pertusa* calcifies at one of the lowest saturation states recorded for any framework building coral ($\Omega=1.2$). Here, we present an additional three years of investigation into carbonate chemistry dynamics at a range of depths (0–3400 m) in the Gulf of Mexico. At deep-water sites with *L. pertusa*, total alkalinity averaged 2310 ± 22 $\mu\text{mol/kg}$, pHT averaged 7.88 ± 0.07 , and Ω_{arag} had an average value of 1.38 ± 0.13 . Additional water samples will be collected and analyzed during a cruise in April 2014.

In addition to monitoring for temporal shifts in carbonate chemistry, it is important to understand the energetic mechanisms that allow corals to calcify at low saturation states; a critical step in predicting their resilience to future acidification. Capture rate, respiration, and calcification rates will be measured for sixteen *L. pertusa* fragments under three treatments: baseline (approximating in situ conditions, $\Omega_{\text{arag}}=1.4$), slightly acidified ($\Omega_{\text{arag}}=1.0$), and highly acidified ($\Omega_{\text{arag}}=0.8$). Preliminary testing with a small number of samples ($n=4$) was conducted for the baseline treatment. Measured respiration rates averaged 0.31 ± 0.14 $\mu\text{mol O}_2/\text{min/gDW}$, the average capture rate was 1.4 ± 0.45 *Artemia* sp. adults/polyp/hr, and net calcification averaged 0.007 ± 0.0007 %/day. It is expected that acidified conditions will increase the energetic costs of calcification, resulting in a trade-off between the production of skeletal material and other physiological processes. However, highly acidified conditions are still expected to result in reduced or even negative calcification rates because it will be too costly to produce skeletal material at a high enough rate to counter the dissolution of exposed skeleton. These results should provide insight into the energetic mechanisms that currently allow *L. pertusa* to calcify at low saturation states, as well as its potential for growth and survival under future acidification scenarios.

Keywords: Ocean acidification, cold-water coral, deep sea

Oral presentation

Carbonate system variability and buffer capacity in a Mediterranean estuarine area (Gulf of Trieste, Northern Adriatic Sea)

Giani M., Ingrosso G., Kralj M., Cibic T., Fabbro C., Karuza A., De Vittor C. and Del Negro P.

The negative impacts of ocean acidification could be relevant in coastal ecosystems, where marine life is concentrated and human impact can act synergically. However, changes in pH in these areas are difficult to study because result from a multitude of physical and biological drivers, including watershed processes, nutrient inputs, and ecosystem metabolism.

The Gulf of Trieste, which lies in the northernmost part of the Adriatic Sea, is a shallow semi-enclosed coastal area influenced by freshwater input and by the inflow of the Eastern Adriatic Current. In the framework of MedSeA (Mediterranean Sea Acidification in a changing climate) programme, seasonal variations of the carbonate system and of the biogeochemical parameters were investigated for 2 years along a transect from the Isonzo river mouth to the centre of the Gulf. The carbonate system was determined by spectrophotometric pH measurement and open-cell potentiometric titration of total alkalinity. The biological influence on CO₂ system due to organic matter production and decomposition was estimated. The measurements showed a wide seasonal variability of the carbonate system. In winter, a marked dissolution of atmospheric CO₂ determined by very low seawater temperature (min 2.88°C) and storms events resulted in high inorganic carbon (CT) concentration. During warm seasons, the surface CT concentration gradually decreased, due to primary production process and CO₂ degassing. Under the pycnocline the degradation of organic matter and the respiration were the prevalent processes, contributing to a low dissolved oxygen concentration (155.7 μmol kg⁻¹), to an increase of inorganic nutrients, and to a strong acidification of bottom waters (pH_T = 7.878). The pH_T minima occurred just after periods of intense prokaryotic activity, linking the intensified subpycnocline acidification to microbial respiration, as explained by a significant linear correlation between in situ pH_T and prokaryotic production.

The overall high total alkalinity observed in the Gulf of Trieste (max 2933 μmol kg⁻¹), higher than in other estuarine areas, contribute to maintain the acidification under the limit of carbonate undersaturation. The buffer capacity of the system was one of the highest in the Mediterranean basin. The riverine input increased the total alkalinity due to chemical weathering of carbonate rocks from the surrounding karstic watershed. However, the recent years were characterised by a strong reduction of rivers discharges and by a more frequent inflow of low alkalinity offshore waters: if this process will continue in the future, a decrease in total alkalinity concentration and a reduction of seawater buffer capacity could occur.

The Gulf of Trieste exhibits an annual variability of pH_T (~0.35) similar in magnitude to 50 year projections of global ocean acidification, demonstrating the highly dynamic nature of the coastal marine carbon system. This high variability and extreme low pH_T events in a short time scale may already exert significant pressure on the marine organisms and ecosystems, highlighting the importance to increase coastal monitoring of marine carbon parameters and the environmental variables which drive these changes.

Keywords: acidification, estuary, pH, buffer capacity

Poster presentation

The combined effect of pCO₂ and temperature increase on bacterioplankton in the Eastern Mediterranean

Giannakourou A., Pitta P., Konstadinopoulou A., Tsiola A., Stroglyoudi E., Zeri C., Gogou A., Giannoudi L., Fragoulis C., Krasakopoulou E.

Bacterial communities play an important role in organic matter cycling and the carbon balance in the future ocean. Ocean acidification and warming can affect directly or indirectly microbial processes through changes in seawater pH, however little is known about the response of marine microbes. The combined effects of ocean acidification and increased temperature were investigated during a microcosm experiment and a large scale mesocosm study in the Eastern Mediterranean, within the framework of the MedSeA project (FP7-ENV-2010-265103) 'Mediterranean Sea Acidification in a changing climate'.

A laboratory 15-day incubation experiment, comprising natural 5µm filtered seawater collected from a coastal area of Saronikos Gulf (E. Mediterranean), was conducted in March 2013. Experimental bottles were incubated in triplicate under present-day and predicted for the year 2100 pH conditions, at two temperatures (T=18°C and 21°C). The mesocosm experiment was performed at the HCMR land-based mesocosm facilities in Crete, (CRETACOSMOS <http://mesocosm.eu/cretacosmos>), during late August/early September 2013, with no nutrient addition in order to simulate the ultra-oligotrophic environment of the E. Mediterranean. The experimental design provided the opportunity to test simultaneously the effects of ocean acidification and warming. In total 12 mesocosms of 3 m³ were deployed in two large concrete tanks for 2 weeks, simulating per three mesocosms the current temperature and pCO₂ conditions (also served as control) as well as the Ocean Acidification, Warming and Green House conditions.

In both experiments, the responses of bacterial parameters to ocean acidification and warming were investigated: bacterial and virus abundance, bacterial production, ectoenzymatic activities (aminopeptidase, β-glycosidase, alkaline phosphatase) important for the decomposition of organic matter as well as heterotrophic bacterial predator abundance/competition to autotrophic cells that could alter the transfer of carbon between bacteria and protists.

Leucine incorporation rates increased with temperature and bacterial production seemed more likely dependent on temperature. Interestingly, under the same temperature values, bacterial growth rates increased at the higher pCO₂ level. Heterotrophic bacteria abundance did not vary among different pH treatments. Preliminary results indicate that autotrophic prokaryotes (*Synechococcus*) and picoeukaryotes were favored at higher temperature values, with a concomitant significant increase in β-glycosidase or aminopeptidase activity pointing to a more intense degradation of polysaccharides or proteins respectively. Results from the mesocosm study confirm that when alkaline phosphatase activity showed higher values under warm conditions it remained suppressed at lower levels in the Green House (warmed and acidified) mesocosms. Furthermore, the influence of seawater pH and temperature on heterotrophic micropredator abundance and their role in competitive interactions within the food web will be discussed. Changes at the base of the food web and organic matter turnover could affect organic matter flow to higher trophic levels and provoke shifts in plankton community composition and food web functioning.

Keywords: Ocean acidification, warming, bacterioplankton, E. Mediterranean

Oral Presentaiton

Effect of increased CO₂ and dissolved iron on primary productivity and inorganic carbon uptake during a bloom of the coccolithophore *Emiliana huxleyi*

Iñiguez C., Lorenzo M.R., Segovia M.

Net primary production (NPP) and inorganic carbon uptake were analysed during a bloom of *Emiliana huxleyi* in mesocosms. The experiment lasted 25 days and was carried out in the Raunefjord off Bergen (Norway, June 2012) in order to investigate the interactive effects of increased CO₂ and iron availability on the phytoplanktonic community. For this purpose two different partial pressures of CO₂ corresponding to present (390 ppmV) and predicted levels for year 2100 (900ppmV) (LC and HC respectively) were used. The siderophore desferoxamine B (DFB) was added to half of the mesocosms to create two different iron conditions (+DFB and -DFB). Three mesocosm bags were used for each treatment.

NPP was estimated using short-term ¹⁴C uptake assays. The isotope disequilibrium assay (ID) was used to determine the relative fraction of HCO₃⁻ and CO₂ uptake in concentrated cell suspensions. Short-term cellular ¹⁴C fixation was monitored during a transient disequilibrium between ¹⁴CO₂ and H¹⁴CO₃⁻ in solution, and so, the fraction of HCO₃⁻ uptake (f) and the rate of extracellular CO₂: HCO₃⁻ interconversion (α), as a measure of extracellular carbonic anhydrase activity (eCA), were calculated. Our results showed an increase in NPP (per volume of fjord water) from day 9 until day 16 in LC+DFB (8-fold higher compared to the rest of the treatments), corresponding to the beginning of the bloom of *E. huxleyi* and the maximum peak, respectively. From this day onwards, NPP decreased in this treatment due to the end of the bloom. NPP showed a similar trend over time in all of the treatments except for LC-DFB on day 19, where a recovery of *E. huxleyi* abundance at the end of the experiment was recorded.

NPP (chlorophyll a (Chl a) normalised) increased from days 9 to 14 in all treatments except in LC-DFB as a result of significant increases in *E. huxleyi* proportion respect to the other taxonomic groups conforming the phytoplankton community. NPP per Chl a showed the highest values in LC+DFB. These results are explained attending to the low content of Chl a in *E. huxleyi*.

The f value obtained for all treatments indicates a high rate of HCO₃⁻ uptake within the community over time, which is a common and widespread characteristic of phytoplankton communities in diverse ocean waters, from equatorial to polar regions. Our results are in agreement with former studies demonstrating that HCO₃⁻ utilisation is largely unaffected by changes in iron availability and primary productivity. The highest α value was obtained at the beginning of the experiment, when diatoms dominated the community. On the contrary, the low α values obtained when the *E. huxleyi* bloom started (3-fold lower compared to initial values), indicates a very low or even inexistent eCA activity in the blooming strain.

As concluding remarks our results show that net primary production was enhanced as a direct consequence of the *E. huxleyi* bloom, by the combination of increased iron availability and present (390 ppmV) CO₂ partial pressures. Increased CO₂ partial pressures (900 ppmV) negatively affected the bloom development, and subsequently, net primary production.

Keywords: Mesocosm, ocean acidification, desferoxamine-B, primary production, isotope disequilibrium

Poster presentation

The combined effects of elevated CO₂ and temperature on the physiological conditions of olive flounder larvae, *Paralichthys olivaceus*

Kim K., Kim S.

Since the industrial revolution, elevated CO₂ in the atmosphere are causing the Ocean acidification and Global warming. This study investigated that the effects of both climate problems on the early development stage of olive flounder *Paralichthys olivaceus*. Fertilized eggs of olive flounder were reared during 4 weeks from fertilization in artificial conditions. Rearing conditions were decided based on the climate change scenario in IPCC report 2007, and combined 3 different CO₂ concentrations (400-present day, 850 and 1550 ppm) with 2 different temperatures (18 and 22 °C). During experiment of rearing, larvae were sampled once a week, these samples were used to calculate of the Growth rate. After 4 weeks, all live larvae were sampled and measured length and weight. In addition, to check skeleton malformation, we used skeleton 2-color dying method and bone density were examined for differences using scanning electronic microscope(SEM). Also, we researched the hatching rate among the different conditions in order to check the effects of changing environment on the hatching rate. Results of experiment, growth was increased with increasing CO₂ concentration in the rearing water. However, skeleton was influenced the negative effect by high CO₂ concentration in the rearing water.

Keywords: Ocean acidification, ocean warming, fish larvae, olive flounder, *Paralichthys olivaceus*

Oral presentation

The Effects of Ocean Acidification and Siderophore Additions on Trace-Metal Dynamics during an *Emiliania Huxleyi*-Dominated Bloom in a Coastal Mesocosm Experiment

Lorenzo M.R., Maldonado M.T., Lázaro F.J., Cullen J.T. and Segovia M.

The combined impacts of high CO₂ and changes in trace metal availability on plankton remain largely unknown. A 22 days, mesocosm experiment was carried out in the Raunefjord, off Bergen, Norway (June 2012) to investigate the interactive effects of increased CO₂ and changes in iron availability in the pelagic community. Twelve mesocosms covered by PAR and UVR transparent lids were used. The CO₂ treatments consisted of present (LC; 390 ppmV) and predicted levels for year 2100 (HC; 900 ppmV). On day 7, half of the mesocosms were amended with the siderophore desferrioxamine B (DFB) at 70 nM (final concentration). We studied changes in dissolved Cu (dCu) and Fe (dFe), and in the elemental composition of particles. Dissolved Fe and dCu were measured by chemiluminescence flow injection analysis, while particulate metals were determined by high-resolution inductively coupled mass spectrometry. The metals were normalised to P and Al to evaluate the relative influence of biotic and abiotic sources. Samples were taken throughout a bloom of the coccolithophore *E. huxleyi*. All mesocosms had indistinguishable dissolved Cu levels, ranging from 7-9 nM. Before the DFB addition, dFe was comparable among treatments (4-5 nM). By day 17, dFe varied among treatments, with HC and/or +DFB treatments exhibiting the highest dFe levels (~12 nM). The control (LC-DFB) maintained the same initial dFe concentration (~4-5 nM). These results suggest that the addition of DFB and/or high CO₂ increased dissolved Fe. Furthermore, by day 21, the +DFB treatments were the only ones maintaining high dFe, regardless of the CO₂ level. This also suggests that the DFB addition enhanced the solubility of Fe in this fjord environment. Particulate Fe ($\mu\text{g L}^{-1}$) decreased in all treatments from day 12 to 21. The lowest Fe concentration was measured in the HC+DFB treatments. Particulate Cu ($\mu\text{g L}^{-1}$) significantly decreased in the HC+DFB treatments, while increased in the LC-DFB treatments. The Cu:P ratios decreased in all mesocosms from day 12 to 17. On day 17, the lowest Cu:P were measured in the LC-DFB treatments, which were 4-fold lower than those in the remaining treatments (0.0003 vs. 0.00125 molCu:molP). These low Cu:P ratios are similar to those reported for phytoplankton. Over time, the Cu:Al ratios increased in all mesocosms, except in the control treatments (LC-DFB) (0.002 vs. 0.05 molCu:molAl). Our measured Cu:Al ratios are ~ 6-fold higher than crustal Cu:Al ratios. The Fe:P ratios in all mesocosms increased with time, ranging from 0.006 to 0.12 (molFe:molP). These ratios compare to published phytoplankton ratios and possibly suggest Fe storage. By day 17, the Fe:P ratios were lowest in the +DFB treatments, regardless of CO₂ levels. Trends for Fe:Al were less obvious. The average mesocosms Fe:Al ratio was ~0.5 (molFe:molAl), higher than crustal Fe:Al ratio. Only the LC-DFB treatment showed a significant decrease in Fe:Al over time. On day 17, the ranking of metal abundance in particles in LC-DFB was: P>Al>Zn=Fe>Ti>Mn=Cu>Co>Mo=Ni>Pb=Cd. This ranking was significantly different than the rankings in all the other treatments. Further details will be discussed.

Keywords: Mesocosm; ocean acidification; DFB; Dissolved iron, Dissolved copper, Particulate metals

Poster presentation

Pteropod race for life: behavioural responses to anthropogenic climate change

Manno C., Primicerio R., Peck V., Tarling G.

Anthropogenic carbon dioxide emissions induce ocean acidification, thereby reducing carbonate ion concentration, which may affect the ability of calcifying organisms to build shells. Pteropods, the main planktonic producers of aragonite in the world's oceans, may be particularly vulnerable to changes in sea water chemistry. The negative effects are expected to be most severe at high-latitudes, where natural carbonate ion concentrations are low. In this study we investigated the combined effects of ocean acidification (OA) and freshening on the swimming behaviour of polar (*L. helicina*) and subpolar (*L. retroversa*) pteropods. Limacina swim by means of paired muscular wings that extend upwards out of the shell aperture. Upward motion of the pteropods is a result of downward strokes of the wings. Living pteropods, collected in subarctic and arctic regions, were exposed to four different pH values ranging from the pre-industrial level to that forecasted for the end of century. Since, over the past half-century, those regions have experienced a progressive freshening, each pH level was combined with a gradient in salinity (S) in two factorial, randomized experiments investigating swimming behaviour and survival. Swimming was monitored by a video camera for 15 min per treatment. We observed that OA affected the ability of pteropods to swim (changing in upward speed and wing beat frequency) only when freshening occurred at the same time. Furthermore, under the synergistic impact of reduced pH and S, survival was also affected and the pteropods started to die after few days, with polar pteropod mortality being higher than that in the sub-polar species. The pteropods were capable of counteracting OA and freshening when stress factors were not combined in the experiments. When stress factors occur concurrently, the extra energy required to avoid shell dissolution (reduced pH environment) and shell sinking (reduced S environment) probably exceeds the available energy budget, affecting first behavior and then survival. Differences in levels of mortality between species suggest the greater capacity of the subpolar *L. retroversa* to counteract anthropogenic climate change compared to the polar *L. helicina*. *L. retroversa* has a larger natural tolerance to variations in salinity and temperature than *L. helicina* which may make it more preadapted to the future changes in climate. Understanding whether or not polar pteropods will be replaced by sub-polar species is an important detail to be included in studies of polar foodwebs and carbon budgets.

Keywords: pteropods, Ocean Acidification, behaviour, freshening

Oral presentation

Effect of ocean warming and acidification on a plankton community in the NW Mediterranean Sea

Maugendre L., Gattuso J.P., Louis J., de Kluijver A., Marro S., Soetaert K. and Gazeau F.

The effect of ocean warming and acidification was investigated on a natural plankton assemblage from an oligotrophic area, the bay of Villefranche (NW Mediterranean Sea). The assemblage was sampled in March 2012 and exposed to the following four treatments for 12 days: control (360 μatm , 14°C), elevated pCO₂ (600 μatm , 14°C), elevated temperature (360 μatm , 17°C), and elevated pCO₂ and temperature (600 μatm , 17°C). Nutrients were already depleted at the beginning of the experiment and the concentrations of chlorophyll a, heterotrophic prokaryotes and viruses decreased, under all treatments, throughout the experiment. There were no statistically significant effects of ocean warming and acidification, whether in isolation or combined, on the concentrations of nutrients, particulate organic matter, chlorophyll a and most of the photosynthetic pigments. Furthermore, ¹³C labeling showed that the carbon transfer rates from ¹³C-sodium bicarbonate into particulate organic carbon were not affected by seawater warming nor acidification. In contrast to the other species, the abundance of cyanobacteria increased throughout the experiment and was higher at elevated temperature, irrespective of the pCO₂ level. Rates of gross primary production followed the general decreasing trend of chlorophyll a concentrations, but was significantly higher under elevated temperature. These results suggest that under nutrient depleted conditions in the Mediterranean Sea, ocean acidification has a very limited impact on the plankton community and that small species will benefit from warming with a potential decrease of the export and energy transfer to higher trophic levels.

Keywords: climate change, oligotrophic area, plankton community

Oral presentation

An International Coordination Centre promoting cooperative actions that address ocean acidification

Hansson L., Orr J., Osborn D. and Warnau M.

As research activities on ocean acidification and related stressors continue to develop, there is a growing need for international collaboration and coordination. Following a call by leading scientists for an international effort to coordinate, promote and facilitate science and related activities concerning ocean acidification, the Ocean Acidification International Coordination Centre (OA-ICC) was established by the IAEA, with direct and in-kind contributions from 7 of its Member States (Australia, France, Italy (ENEA), Japan, New Zealand, UK and USA) and key international projects (including IMBER, SOLAS and MedSeA). Now in its second year of operation, the OA-ICC promotes a series of overarching international activities to serve not only the scientific community but also science users, including policy makers, media, and the general public. Among its activities, the OA-ICC is helping to establish an international observing network, promoting joint use of research platforms and experiments, stimulating collaboration between natural and social sciences, facilitating updates to recommendations for best practices, building science capacity especially in developing countries, and communicating science to non-scientists. Its related science products include (1) the *OA-ICC news stream* (news-oceanacidification-icc.org) that informs scientists of recent publications, media coverage, meeting announcements, and jobs; (2) the *OA-ICC data compilation on the biological response to ocean acidification* that provides easy access to regularly updated experimental data (<http://tinyurl.com/oaicc-data>); (3) the *OA-ICC bibliographic database* with currently more than 2000 references that include citations, abstracts and keywords to simplify searches and bibliographic statistical analysis (<http://www.iaea.org/ocean-acidification/page.php?page=2196>); and (4) a new publication detailing a comparison of publicly available software to compute carbonate chemistry (a collaboration with IOCCP). For more information about the OA-ICC and its activities, please refer to the OA-ICC web site (iaea.org/ocean-acidification).

Keywords: ocean acidification, outreach, training, observation, database

Poster presentation

Ocean acidification exposes scars from a violent past

Peck V., Tarling G., Tynan E., Manno C. and Harper L.

Pteropods, *Limacina helicina*, collected under sea ice off East Greenland in June 2012 exhibit varying degrees of shell dissolution. Localised areas of dissolution are clearly visible under light microscope in about half of the specimens collected, while others maintained wholly 'pristine' shells. In specimens exhibiting dissolution, the dissolution was localised to discrete sites within an otherwise pristine shell where the protective organic coating of the shell, the periostracum, had been compromised. Damage to the periostracum occurred mechanically, such as where the shell has been broken and regrown and the old and new periostracum did not form a perfect seal or the shell surface has been scratched or punctured. Microbial or epibiont activity on the shells surface may also have damaged the periostracum in some cases. Specimens that appeared to be pristine on collection were subjected to 8 day incubations in conditions simulating subsurface waters at pCO₂ >750 ppm and also began to exhibit dissolution on historical and/or newly acquired sites of periostracum damage at the end of the incubation. SEM images confirm that dissolution was found exclusively in areas where the periostracum had been damaged and the underlying aragonite shell exposed. Several specimens exhibited discrete sites of dissolution so extensive that the full depth of the original shell had been eroded. In these cases, additional aragonite was secreted internally to 'patch up' the damage and maintain a fully intact, rigid shell to protect the animal.

At the time of collection, water down to 300m was supersaturated with respect to aragonite, suggesting that dissolution should not have been active at that time. SEM analysis clearly demonstrates that dissolution of the original shell in specimens exhibiting damage had occurred earlier in the animal's life. Whether these specimens were subject to undersaturated waters during the winter months at this site or within waters, perhaps to the north, where they may have spent their earlier lives is unknown, but exposure of these pteropods to undersaturated waters on one or more occasions over the last year or two has revealed their scars from a violent past. Although these specimens exhibit some shell deterioration they remain robust and demonstrate the ability of *L. helicina* to maintain their shell and continue to calcify in undersaturated waters. What our results confirm is that for *L. helicina*, as with all molluscs, the periostracum is crucial for secreting and protecting the shell, even in undersaturated conditions and that net dissolution of their shells is an unlikely consequence of ocean acidification within the coming century.

Keywords: Pteropod, ocean acidification, Arctic, sea ice

Poster presentation

Acidification of the Marine Nitrogen Cycle

Rees A.P., Clark D.R., Al-Moosawi L., Brown I.J.

Predicted changes to ocean carbonate chemistry are likely to affect processes and organisms which contribute to the marine nitrogen cycle though we are at an early stage in our understanding and impacts are largely uncharacterised. Ocean Acidification manipulation experiments have been performed in a range of environments from the oligotrophic Mediterranean (MedSeA) to the ice-edge of the summer Arctic and Antarctic Oceans (UKOA). During mesocosm experiments off Corsica and Villefranche, nitrate uptake and nitrification in perturbed environments (6 x CO₂ enrichments up to 1290 µatm) did not differ from controls, in contrast the summertime rates of nitrogen fixation were seen to increase approximately 10 fold when pH levels were in the order of the predicted 100 year scenario. Similar to our findings in Mediterranean mesocosms but in contrast to other published work, nitrification in surface waters of temperate European seas and the Arctic Ocean proved resilient to all OA manipulations (3 x CO₂ enrichments up to 1000 µatm). We are awaiting the results of nitrification experiments performed at the base of the photic zone in Arctic and Antarctic waters with baited breath as N₂O production proved to be progressively inhibited with increasing levels of CO₂. These data are presented in the context of other published work in order to appraise the current understanding of the pelagic nitrogen cycle in a high CO₂ environment

Keywords: ocean acidification nitrogen mediterranean arctic antarctic

Oral presentation

Ocean acidification – challenges for shell fish aquaculture

Meynecke J.O., Richards R.

Ocean acidification (OA) threatens future food security in particular through impacts on shellfish production. However, ocean acidification has received relatively little attention compared to ocean warming. Carbon dioxide concentrations have risen to values exceeding those experienced in the last million years and at a rate approximately 100 times faster than at any time during this period. Calcifying organisms, which includes economically important species such as oysters and mussels, appear to be particularly vulnerable. Recent studies estimated that the total global cost of mollusc losses to OA by 2100 is as high as 141 billion USD. However, input of acidic riverine discharge can expose organisms occupying the continental shelf waters to persistent or episodic low pH and allow for the development of resistance. There are expected long-term effects of OA on broodstock quality due to impacts on eggs / larvae / juveniles. Several studies have shown that this can cause dissolution of calcified skeletons and reduce rates of calcification by oysters but they also indicate that the vulnerability differs among species. We have analysed the impacts of OA on shell aquaculture based on input from a suit of experts ranging from industry representatives to policy makers. We developed a conceptual model based on a case study from Hervey, Bay in Queensland, Australia and defined what areas are effected by OA and where intervention is possible. This has important implications for predictive modeling and adaptive management capacity in the wild and aquaculture shellfish fishery.

Keywords: Ocean acidification, aquaculture, shellfish, adaptation, modelling

Oral presentation

Plankton community responses to ocean acidification and their impacts on biogeochemical cycling: results from mesocosm studies covering a range of environmental conditions

Riebesell U. and the KOSMOS teams 2010-2014

The growing evidence of potential effects of ocean acidification (OA) on marine organisms implies that this global change phenomenon is likely to impact marine ecosystem functioning and biogeochemical cycling. The information presently available on OA sensitivities of planktonic organisms suggests a great diversity in OA responses. This ranges from adverse effects on growth and calcification in some phytoplankton species to stimulated carbon and nitrogen fixation, growth and organic matter exudation in other groups of phytoplankton. These physiological responses can mediate ecological and biogeochemical impacts. For instance, changes in food quality with regard to size, stoichiometry, and fatty acid composition may affect higher trophic levels. Shifts in community composition and trophic interactions, in turn, can affect elemental cycling and export fluxes. Much of our present knowledge on OA effects is based on single species experiments, with little information about possible impacts on natural communities, food webs and ecosystems. Even less is known about the potential for evolutionary adaptation to OA.

To investigate community-level responses to ocean acidification of pelagic systems a series of mesocosm studies was conducted using the Kiel Off-Shore Mesocosms for Future Ocean Simulations (KOSMOS). These studies covered a variety of geographical and environmental settings, ranging from an Arctic environment off Svalbard (2010), to temperate latitudes off southern Norway (2011), the eastern Baltic Sea (2012), and the west coast of Sweden (2013), to a subtropical oligotrophic system off Gran Canaria (2014). Despite large differences in environmental conditions, some prominent responses to ocean acidification were similar across all studies. OA sensitivities generally differed between pre- and post-bloom conditions. While some OA impacts observed at the individual level in lab-based studies appeared to be dampened through biological buffering, others were strongly amplified or initiated through community level interactions. Plankton community responses to OA were found to modulate biogeochemical processes and air-sea exchange of climate relevant gases. These results highlight the importance of applying systemic approaches to studying biological responses to ocean change.

Keywords: ocean acidification, plankton community, mesocosms

Oral presentation

Interactive effects of increased CO₂ levels and iron availability on the marine pelagic food web during a mesocosm experiment

Segovia M., Lorenzo M.R., Maldonado M.T., Larsen A., Lázaro F.J., Iñiguez C., Palma A., García-Gómez C., Berger S.A., Mausz M., Simonelli P. and Tsa T.M.

A mesocosm experiment was carried out in the Raunefjord, off Bergen, Norway (June 2012) to investigate the interactive effects of increased CO₂ and iron availability on the pelagic food web. Twelve mesocosms (11m³) covered by PAR and UVR transparent lids were used. The seawater carbonate system in the mesocosms was manipulated to achieve two different CO₂ levels, corresponding to the present (390 ppmV, LC) and to levels predicted for year 2100 (900 ppmV, HC). Mesocosms were fertilised at the onset of the experiment, by addition of 10 μM nitrate and 0.3 μM phosphate to induce a bloom of the coccolithophore *Emiliana huxleyi*. On day 7 of the experiment, half of the mesocosms were amended with 70 nM (final concentration) of the siderophore desferoxamine B (DFB), resulting in a ~3-fold increase in dissolved iron (dFe) in both HC and LC treatments by day 17. HC treatments also increased dFe ~3-fold. During the experiment, the plankton community structure shifted, and two distinct phases were observed. The first phase (experiment days 0-8) was dominated by picoeukaryotes (0.1 to 2 μm) and small nanoeukaryotes (2-7 μm), followed by large nanoeukaryotes (6-20 μm) and *Synechococcus*. No significant differences between treatments were observed in these first 8 days. In the second phase (days 9-22), a community response to both treatments (CO₂ and Fe) was evident. The abundance of *E. huxleyi* in the LC treatments increased ~4-fold relative to other autotrophic groups when DFB was added, and it also became the dominant species in mesocosms without DFB. In contrast, HC had a clear negative effect on *E. huxleyi* abundance, growth rates and cellular particulate calcium. Regardless of the CO₂ level, the increase in dFe favoured *E. huxleyi* growth, especially in the LC treatment, where the 3-fold increase in dFe resulted in a doubling of *E. huxleyi* cell densities. Similarly, *Synechococcus* abundance was higher in the LC treatment, and was further enhanced in the treatment with high dFe. Initially, small nanoeukaryotes abundances dropped off but were followed by a recovery, which was faster under LC; suggesting that HC negatively affected their growth rates during the second phase. Picoeukaryotes, large nanoplankton, viral abundance and ciliates were not affected by changes in CO₂ or dFe levels. Primary productivity matched the two biomass peaks observed. The bacterial community showed a significant positive response to HC but it was unaffected by Fe levels. Total mesozooplankton abundances did not change significantly, although the response of specific taxonomic groups to the treatments varied. The data obtained show that within the pelagic community, phytoplankton were the most sensitive organisms to changes in CO₂ and Fe levels. This is the first mesocosm study to show an enhancement of *E. huxleyi* growth at present CO₂ levels by an increase in dFe in a cold-temperate fjord. We have demonstrated that HC is detrimental to *E. huxleyi*, supporting previous evidence. We suggest that the negative effect caused by HC was partially counterbalanced by the presence of available dFe. The relevance of these results within a global biogeochemical perspective will be discussed.

Keywords: High-CO₂, iron, pelagic food web, mesocosms

Oral presentation

Impact of Ocean Acidification on the Growth and Ultrastructure of Non-calcifying Marine Diatom (*Chaetoceros gracilis* F. Schütt)

Khairy H.M., Shaltout N.A., El-Naggar M.F., El-Naggar N.A.

The combined impacts of future CO₂ and high temperature (28°C) on the growth, physiology and ultrastructure of non-calcifying microalga *Chaetoceros gracilis* F. Schütt (Diatom) were studied. We incubated *Ch. gracilis* under different CO₂ concentrations, preindustrial and current ambient atmospheric concentration (285 and 385 μatm, respectively) or predicted year-2100 CO₂ levels (550, 750 and 1050 μatm), and under high temperatures (28°C) in continuous culture condition. The growth of *Ch. gracilis* measured as cell number was decreased by increasing pCO₂ concentration from nowadays concentration (385 μatm) to 1050 μatm. The lowest percentage changes of oxidizable organic matter, nitrite, nitrate, phosphate and silicate were recorded at higher pCO₂ (1050 μatm), and this is in consistence with the lowest recorded cell number indicating unsuitable conditions for the growth of *Ch. gracilis*. The minimum cell numbers obtained at higher levels of CO₂ clearly demonstrate that, low improvement in when the carbon level was raised. This was confirmed by a highly negative correlation between cell number and carbon dioxide partial pressure ($r=-0.742$). On the other hand, highest growth rate at pCO₂ = 385 μatm was also confirmed by the maximum uptake of nutrient salts (NO₃ = 68.96 μmol.l⁻¹, PO₄=29.75 μmol.l⁻¹, Si₂O=36.99 μmol.l⁻¹). Total protein, carbohydrate and lipids composition showed significant differences ($p \leq 0.05$) at different carbon dioxide concentrations during exponential growth phase (day 8). Transmission Electron Microscopy of *Ch. gracilis* showed an enlargement of the cell, chloroplast damage, disorganization and disintegration of thylakoid membranes and cell lysis occurs at higher CO₂ concentration (1050 μatm). It is concluded from this regression equation and from the results that the growth of *Ch. gracilis* expected to decrease by increasing pCO₂ and increasing ocean acidification.

Keywords: Ocean Acidification, Carbonate Chemistry, *Chaetoceros gracilis*

Poster presentation

Modelling the state of the Mediterranean Sea under contemporary and future climate

Solidoro C., Lazzari P., Cossarini G., Melaku Canu D., Vichi M., Lovato T., Scardi M., Fraschetti S., Martin C. and Giannoulaki M.

A three-dimensional coupled transport-biogeochemical model is used to assess the impact of future climatic and management scenarios on biogeochemical and ecological properties of the Mediterranean Sea. Results are discussed in terms of temporal and spatial distribution of parameters and indicators related to the carbonate system and the cycles of carbon and inorganic nutrients through dissolved and particulate phases, as simulated by a multi-nutrient multi-plankton numerical model under current and future climate conditions. Simulations span the period 1990-2040 and are performed by forcing a three-dimensional off-line coupled eco-hydrodynamical model (BFM and OPA-tracer model) with current fields produced by ad-hoc implementation of the NEMO modelling system and with river input of nutrient and freshwater computed in recent European FP7 projects (such as Persus and MedSeA).

The model properly describes available experimental information on contemporary seasonal dynamic and spatial distribution at the basin and sub-basin scale of major biogeochemical parameters, as well as primary production and carbon fluxes at the air-ocean interface. Model projections suggest that future Mediterranean Sea will be as a whole warmer, more productive, and more acidic, but with significant space variability.

Implications in terms of ecological and higher trophic level organisms dynamics are discussed, with reference to aquaculture activity and biogenic habitats (*Posidonia oceanica* seagrass, coralligenous formations, maerl beds).

Keywords: models, climate, biogeochemistry, habitat

Oral presentation

Metabolic responses different Mediterranean invertebrate species to high CO₂ and low O₂

Steckbauer A., Hendriks I., Duarte C.M.

Due to anthropogenic influences, ocean acidification and hypoxic events are an increasing problem worldwide. Although there is an increasing interest the synergetic effects of these factors are seldom explored. The coastline of the Mediterranean Sea not only suffers from coastal hypoxia but also from different threats as eutrophication, increasing temperature, habitat loss and degradation, fishing impacts, pollution, and the establishment of alien species. Especially in the coastal ecosystems these impacts are expected to grow in importance in the future, which makes it a perfect study site. In this work we evaluated experimentally the metabolic response of different invertebrate species (9 molluscs, 5 crustaceans, 1 echinoderm, 1 polychaete) of different sites along the coastline of Mallorca, Spain, to hypoxia and high CO₂ within predicted levels and in a full factorial design. Model organisms were exposed to 4 different treatments (ambient, hypoxia, high CO₂ and hypoxia&high CO₂) and metabolism was measured after 3 days. The main results show that the combination of hypoxia and increased p CO₂ reduces the respiration significantly, compared to single stresses. This is a first step in evaluating future global changes to coastal species and might give us a first impression on what will happen in 100 years as predicted by the IPCC report.

Keywords: Ocean acidification, high CO₂, hypoxia, invertebrates, respiration

Oral presentation

Effects of acidification and warming on a coastal Mediterranean plankton food web: the WARMACIDWEB mesocosm experiment

Vidussi F., Luchetta A., Cantoni C., Le Floc'h E., Mas S., Pete R., Parin D., Roques C., Fouilland E., Liagre M., Dinet T., Pecqueur D., Annane S., Ape F.

Coastal and continental shelf regions constitute the most diverse and productive systems of the world's oceans providing substantial ecosystem services. Hence, understanding how climate change will impact the functioning of these productive ecosystems is a main ecological and economic challenge. Here we investigated the potential effect of the projected climate change scenarios on the structure and functioning of a coastal plankton community by using an in situ mesocosm approach in the coastal Mediterranean Thau lagoon. This lagoon is an important European shellfish farming area sustaining 10% of the French oyster production. Twelve mesocosms (about 2300 L each, 2 m depth) were deployed in the lagoon and filled with natural surrounding waters. Mesocosms were manipulated to perform four treatments each in triplicates: i) water pCO₂ increase, ii) water temperature increase, iii) both water pCO₂ and temperature increases, and iv) natural water pCO₂ and temperature conditions. Water temperature was increased by 3°C using submersible heating elements and water pCO₂ was increased to approximately 900 µatm through the addition of CO₂ enriched seawater. In the middle of the experiment all mesocosm were fertilized with dissolved inorganic nutrients to mimic a wind-driven nutrient event. Water temperature, salinity, pH, dissolved oxygen concentrations and chlorophyll fluorescence were monitored at high frequency (2 minutes) in real time using autonomous sensors set in the mesocosm units. Discrete water samplings were performed daily during 12 days to investigate the dynamic of chemical parameters and plankton abundances, diversities and productions under the different treatments. The phytoplankton bloom peaked two days after the nutrient addition with chlorophyll a concentrations reaching 4.7 µg L⁻¹. Two independent measurements of chlorophyll a concentrations (HPLC and continuous in situ fluorescence monitoring) showed that acidification tends to enhance phytoplankton biomass. Diatoms, in particular, tend to increase under acidification as highlighted by pigment biomarkers. Shifts in plankton communities' structure, as well as interactions between acidification and temperature increases will be further discussed.

Keywords: temperature, acidification, plankton, mesocosms, Mediterranean, coastal

Poster presentation

Effects of raised CO₂ and Temperature on composition, production and feeding behavior of marine copepods during mesocosm experiments in the Mediterranean Sea.

Zervoudaki S., Krasakopoulou E., Gazeau F., Pitta P., Moutsopoulos T., Grigoratou M., Protopapa M., Frangoulis C., Giannakourou A., Guieu C. and Ziveri P.

The Mediterranean Sea is one of the most nutrient-poor regions of the global ocean, with a trophic status ranging from mesotrophic in the northwest to extremely oligotrophic in the east. Both acidification and warming are expected to alter the ecology of the Mediterranean significantly, although the evidence to date is sparse. To our knowledge, the combined effects of warming and acidification on specific marine organisms such as copepods, inhabiting the Mediterranean Sea are poorly investigated. Copepods are one of the most important zooplankton components and play major roles in the structure and functioning of marine planktonic food webs. In the frame of MedSeA project (FP7-ENV-2010-265103), two large-scale experimental studies (mesocosm experiments) were performed in the Mediterranean Sea in order to identify how pH and temperature changes will influence biological interactions and fluxes among organisms and across trophic levels. In the first experiment, large-scale in situ mesocosms (54 m³) have been used to quantify these potential effects in the Western Mediterranean Sea (Bay of Calvi, France) in June/July 2012. Nine mesocosms were deployed for a period of 30 days. Six of them were subjected to different levels of pCO₂ (550, 650, 750, 850, 1000 and 1250 µatm) covering the range of atmospheric pCO₂ anticipated for the end of this century and the last three mesocosms were unaltered with a pCO₂ of ~ 450 µatm corresponding to the pCO₂ of surface waters in June/July at Bay of Calvi. The second one was performed in the Eastern Mediterranean (S. Aegean Sea, Greece) in August/September 2013 at the land-based mesocosms facilities of CRETACOSMOS. Two different pCO₂ (present day and predicted for 2100) were applied in triplicate mesocosms of 3 m³ and tested in two different temperatures (ambient seawater (25°C) and ambient plus 3°C). In total twelve mesocosms were deployed in two large concrete tanks for 2 weeks. In both experiments, we examined the effect of acidification and warming (only at the second) on the secondary production, composition and feeding behaviour of keystone Mediterranean copepod species. Copepods were the dominant group followed the distribution of the total zooplankton in both experiments. Among copepods the dominant species were *Acartia clausi* and *Centropages typicus* in the W. Mediterranean, whereas *Clausocalanus furcatus* and *Temora stylifera* dominated in the E. Mediterranean. Copepod production (CP) varied with time in both experiments and a significant difference between the mean CP and the duration of the experiments was detected. Acidification had no clear effect on CP in both experiments, whereas acidification and warming resulted in a significant decline of CP and this decrease was higher than that observed by warming only. Clearance rates of *A. clausi* and *C. typicus* on chlorophyll a and microplankton revealed that there are no significant differences among the CO₂ levels. We hope the results provided here will help to gain insight of the dynamics and trophic efficiency of food web at different pCO₂ levels and temperatures and may allow better predictions of the overall effect of ocean acidification and warming on the functioning of marine ecosystems.

Keywords: ocean acidification, warming, plankton, Mediterranean Sea

Oral presentation

Biodiversity of coccolithophores and *Emiliana huxleyi* calcite mass from surface sediments of the Mediterranean Sea in a changing climate

Grelaud M., [Ziveri P.](#)

Coccolithophores are an abundant marine phytoplankton group that plays a significant role in both the marine food web and the carbon cycle. They are responsible for the photosynthetic fixation of inorganic carbon, regulating the particulate inorganic-organic carbon ratio and a large portion of the calcium carbonate (CaCO₃) production. In this study, we investigate the synergistic effect of multiple environmental parameters (temperature, salinity, nutrient, and seawater carbonate chemistry), on the biodiversity of coccolithophores and the calcite mass of the most abundant species, *Emiliana huxleyi*, in 63 surface sediment samples retrieved all around the Mediterranean Sea. We focus on the effect of warming and acidification both resulting of higher atmospheric CO₂ concentrations. The first results of this work show that both the averaged calcite mass of *E. huxleyi* coccoliths and the biodiversity index of coccolithophore community (i.e. Shannon Index) tend to increase across the Mediterranean Sea from the western to the eastern basin. Moreover, the biodiversity and the averaged calcite mass present significant correlation with temperature, nutrients availability, pH and pCO₂. These results suggest that increasing sea surface temperature and associated stratification, as well as ocean acidification may have a potential impact on these calcifiers, which are within the most significant primary producers of the world ocean.

Keywords: coccolithophores, Mediterranean, biodiversity, CO₂

Poster presentation

Mediterranean Sea acidification in a changing climate: the European MedSeA project

Ziveri P. and MedSeA consortium

During the last 40 years the ocean has absorbed one fourth of the human-induced atmospheric CO₂ and about 80% of the increased heat. As consequences of these processes, ocean acidification and warming are rapidly altering the physico-chemical seawater properties with consequences for the marine ecosystems and ecosystem services. At the regional scale, these processes threaten the health of the Mediterranean Sea adding to other man-made environmental pressures. The Mediterranean Sea is both too complex and too small to be adequately resolved in global-scale climate and ocean biogeochemical models. Mediterranean time-series shows that despite a strong seasonal variability in pH, due to air-sea interface exchange, estimated decrease is relatively large and acidification is at its maximum in the surface layer.

The Mediterranean Sea Acidification in a changing climate (MedSeA) is a funded project of the European Commission (7th Framework Programme) assessing uncertainties, risks and thresholds related to Mediterranean acidification and warming at organism, ecosystem and economic scales. We will review here the state of knowledge and new findings related to the combined effect of ocean acidification and ocean warming in the Mediterranean. In this project we focus on organisms that are unique or endemic to the Mediterranean Sea, major contributors to habitat building, and/or ecological function, or species of economic value in the region.

The regional vulnerabilities alter the capacity of coastal and marine systems to provide ecosystem services and consequently affect economic activities and human welfare.

Keywords: acidification, warming, Mediterranean, socio-economic impacts

Poster presentation

Session F3: Impacts of anthropogenic stressors and climate change on biogeochemistry-ecosystem in continental margins and feedbacks to earth system and society: challenges and solutions

Oral Presentations

Tuesday 24 June, 11:00-12:30 Parallel session 1

Chair: Jing Zhang

Room K1

Time	Presenter	Title
11:00-11:20	Castaño-Primo, Rocio	Differential response of the carbonate chemistry in three North Atlantic shelf systems and their underlying processes.
11:20-11:40	Grégoire, Marilaure	Linking management strategies and the status of hypoxia on the Black sea's north-western shelf.
11:40-12:00	Liu, Su Mei	Coupled nitrogen and oxygen isotope measurements of nitrate in the Yellow Sea: a tracer for nitrogen cycling
12:00-12:20	Oguz, Temel	Impacts of anthropogenic stressors and climate change on the Black Sea biogeochemistry and ecosystem
12:20-12:30	All	Discussion

Tuesday 24 June, 14:00-15:30 Parallel session 2

Chair: Helmuth Thomas

Room K1

Time	Presenter	Title
14:00-14:20	Narvaez, Diego	Effects of the shelf circulation in the dispersion of terrestrial inputs in the Northwest Atlantic Ocean
14:20-14:40	Huang, Daji	Temporal and spatial variation of seasonal hypoxia off Changjiang Estuary and its relation to physical forcing
14:40-15:00	Guo, Xinyu	Influence of nutrients with different sources on nutrient distribution and primary production in the East China Sea
15:00-15:20	Du, Chuanjun	On the inter-annual variation of chlorophyll in the South China Sea: importance of the Kuroshio intrusion
15:20-15:30	All	Discussion

Tuesday 24 June, 16:00-17:30 Parallel session 3

Chairs: Hiroaki Saito and Kon-Kee Liu

Room K1

Time	Presenter	Title
16:00-16:20	Saito, Hiroaki	For resolving Kuroshio Paradox and sustainable use of ecosystem services: The Study of Kuroshio Ecosystem Dynamics for Sustainable Fisheries (SKED)

Session F3: Continental margins

16:20-16:40	Roberts, Michael	Science to Governance in marine LMEs: a case study of ecosystem functioning in the Mozambique Channel and the possible mechanisms for addressing management needs related to the impacts of climate change
16:40-17:00	Huang, Bangqin	Phytoplankton community and POC flux in the China Marginal Seas: the Physical-Chemical-Biological Coupling
17:00-17:20	Shiao, Jen-Chieh	Influences of terrestrial discharges on benthic ecosystem in the East China Sea: eutrophication, hypoxia and low fish diversity
17:20-17:30	All	Discussion

Poster presentations

Tuesday 24 June, 17:30 Poster Session 1

ID	Presenter	Title
F3.P1	Cuevas, Luis Antonio	Heterotrophic bacteria and phytoplankton responses to different nutrient ratios in Chilean Patagonian fjords. Importance in the biological pump.
F3.P2	González, Humberto	Chilean Patagonian fjords: The possible impacts of global change on plankton food webs and biological pump in an uncertain ocean.
F3.P3	Hung, Chin-Chang	Can enhanced anthropogenic nutrient loading induce high POC export in the East China Sea?
F3.P4	Hung, Jia-Jang	Distributions and vertical fluxes of dissolved and particulate organic carbon in the northern South China Sea
F3.P5	Kang, Hyoun-Woo	A numerical experiment on the influence of the Changjiang River Discharge on the Lower Trophic Ecosystem in the Yellow and the East China Seas

Differential response of the carbonate chemistry in three North Atlantic shelf systems and their underlying processes.

Castaño-Primo R., Daewel U., Schrum C. and Thomas H.

The increasing concentration of atmospheric CO₂ is the main driver for the long-term trends in the ocean carbon concentrations on a global scale. However, this signal is significantly modulated at regional scales by the physical environment and the ecosystem dynamics. Circulation, stratification, temperature and primary production are some of the processes relevant for the regional specifications in the response to the atmospheric forcing.

The North Sea, the Baltic Sea and the Barents Sea provide good examples of shelf systems with very different dynamics. The North Sea receives nutrient rich Atlantic waters and only its northern sector is seasonally stratified, while the southern North Sea well mixed due to strong tides. On the other hand, in the Baltic Sea the water exchange with the North Sea is severely restricted. One of the main features of the Baltic Sea is the permanent halocline, which leads to long periods of anoxia in the bottom layers of the deep basins. In the Barents Sea, the Atlantic inflow and the seasonal ice coverage are the most prominent features that affect its biogeochemistry.

The aim of this work is to identify and describe the processes behind the specific regional responses of the carbonate system on inter-annual to multi-decadal time scales. The ECOSMO model is run for a 60-years hindcast period (1948-2007) in all three areas. ECOSMO is a 3-D coupled physical-biogeochemical model that includes a module for carbon chemistry. The biogeochemical model resolves the cycles of nitrogen, phosphorus and silicate, includes 3 functional groups of phytoplankton and 2 groups of zooplankton. pH and pCO₂ are calculated from alkalinity and DIC, which are prognostic variables in the model.

The seasonal, annual and peak values of the carbonate variables (alkalinity, DIC, pH and pCO₂) were analysed respect to potential key processes such as temperature, net primary production and water exchange with adjacent areas, in search of significant correlations that could explain the regional long-term trends.

Keywords: Baltic, Barents, North Sea, carbon, bio-physical model

Oral presentation

Heterotrophic bacteria and phytoplankton responses to different nutrient ratios in Chilean Patagonian fjords. Importance in the biological pump

Cuevas L.A., Vargas C.A., Silva N and Iriarte J.L.

Chilean Patagonian fjords are highly dynamic ecosystems influenced by freshwater discharges from rivers of glacial origin as well as surface runoff and ground water flows due to the strong influence of subpolar low-pressure systems associated with high rainfall. At the same time, these fjords and channels are strongly influenced by tidal fluctuations and by sub-surface intrusions of oceanic waters, mainly Sub-Antarctic waters (SAAW) from the South Pacific Ocean. These features set up a strong river-ocean gradient in chemical characteristics with freshwaters loaded with high silicon concentrations and oceanic waters rich in nitrate and phosphate. Furthermore, strong seasonal patterns have been observed in terms of productivity and phytoplankton size structure leading to 'classical' food chain type during productive seasons (spring-summer) versus 'microbial' food webs type during non-productive seasons (autumn-winter).

In order to investigate how potential changes in nutrients loads affects heterotrophic bacteria and phytoplankton, nutrients manipulated experiments were carried out at the Reloncaví fjord in the Chilean Patagonia. Different supply ratios of glucose-C to riverine (silicate enrichment) and to oceanic (nitrate and phosphate enrichment) nutrients were tested. Phytoplankton biomass and community structure responded different to freshwater and oceanic nutrient supplies. In addition, the phytoplankton response decreased with increase of glucose additions. The observed small cells (< 20 µm) and large cells (e.g. microphytoplankton) biomasses lead to an 'un-efficient' microbial and to an 'efficient' classical food web types, respectively. Our results indicated that potential changes in nutrient ratios in this vulnerable ecosystem lead to different food web types, at which the efficiency of the biological pump and the potential exportation of carbon will be affected by the different rates of nutrients observed. Thus, anthropogenic activities such as aquaculture (fish and mussel farms) and the alteration of freshwater discharges (e.g. installation of new dams), will turn N:Si ratios towards values lower than 1, leading to important changes in the dominant food web type and the magnitude of the local exportation of organic matter.

Keywords: Heterotrophic bacteria, phytoplankton, nutrient ratios, fjords

Poster presentation

On the inter-annual variation of chlorophyll in the South China Sea: importance of the Kuroshio intrusion

Du C., Dai M. and Gan J.

Based on the time series data obtained at a region around SEATS (the South East Asia Time Series Station, located at 116°E, 18°N) in the northern South China Sea (SCS), Liu et al. (2013) have shown strongly asymmetric correlations of chlorophyll (Chl) and SST with positive MEI (El Niño) or negative MEI (La Niña) associated with wind speed, SCS throughflow and possibly the intrusion of the nutrient depleted Kuroshio water. Generally, Chl was lower during the El Niño years and higher during the La Niña period. This study sought to further examine the impact of Kuroshio intrusion on the Chl in the SCS.

By applying a three dimensional Regional Ocean Model System (ROMS), the position of North Equatorial Current (NEC), the Kuroshio main stream transport, the water flux through the Luzon Strait were computed and compared with the multivariate ENSO index (MEI). Coupled with an isopycnal mixing model, the Kuroshio water proportion at SEATS was further quantified. After removal of the seasonal signal, the inter-annual variation of the position of the NEC, the Kuroshio transport, the water flux through the Luzon Strait and the Kuroshio water fraction at the SEATS station all showed asymmetric response to the MEI. During the El Niño years, the northward shifts of the NEC position weakens the Kuroshio main stream transport, which subsequently increases the water flux through the Luzon Strait, which ultimately increases the Kuroshio water fraction at the SEATS station.

We found that the Kuroshio water fraction in the SCS was overall higher during the El Niño but lower during the La Niña period, negatively correlating with Chl. As the Kuroshio carries the most oligotrophic water of the world's oceans, its intrusion into the SCS has obviously a dilution effect on the Chl within the SCS. We thus confirmed that the inter-annual variation of Chl concentration in the SCS is significantly modulated by the influx of the oligotrophic Kuroshio water through the Luzon Strait. We must point out that quantitative assessment of the relative contribution between the wind driven inter-annual variation and the intrusion of the Kuroshio is yet to be determined.

Keywords: inter-annual, chlorophyll, South China Sea, Kuroshio

Oral presentation

Chilean Patagonian fjords: The possible impacts of global change on plankton food webs and biological pump in an uncertain ocean.

González H.E., Iriarte J.L., Ardelan M.V., Cuevas L.A., Sanchez N., Silva N., Castro L., Daneri G. and Olsen Y.

Patagonian fjords are highly vulnerable systems where marine and terrestrial influences overlap. Many rivers with high freshwater discharges ($>1000 \text{ m}^3 \text{ d}^{-1}$), set up a strong terrestrial-marine gradients in physical (e. g. stratification), chemical (e. g. salinity, organic matter and nutrients) and biological (e. g. primary production (PP), plankton composition) characteristics/processes. These features show conspicuous seasonal patterns linked with local and remote climate stressors. The productive season (spring-summer period) have shown a Food Web (FW) dominated by large-size plankton components (e. g. chain-forming diatoms, large copepods, euphausiids), and an enhanced efficiency of the Biological Pump (BP) through the production of large-, fast sinking particles such as zooplankton faecal pellets and phyto-aggregates. By contrary, during the non-productive season (autumn-winter), a microbial FW dominated by bacteria, small nanoflagellates and small copepods suppress the efficiency of the BP. In addition, high inputs of freshwater loaded with allochthonous organic matter all year round, obscure the relationship between local PP and export production.

The future outcomes of these processes (and many others) have been challenged in an ocean that experiences an exacerbated global change and increasing aquaculture activities, putting a veil of uncertainty. Thus, the framework of the recently approved “Ocean Certain” EU project identified the Food Web (FW) and the associated Biological Pump (BP) as the large-scale mechanisms for which qualitative and quantitative models must be developed in order to predict the outcomes of different scenarios on various mitigation and adaptation plans with more certainty. Hence this project aims to increase the predictive capacity and subsequently effective management options through increasing our knowledge about the FW and BP. In order to tackle this challenge, different approaches such as data mining and literature based knowledge discovery (LBKD), mesocosm experiments in Chilean Patagonia systems and varied modelling efforts will be conducted.

Funded by Ocean Certain project EU-FP7 Grant 603773 and CIMAR program

Keywords: Patagonia, Food Web, Biological Pump

Poster presentation

Linking management strategies and the status of hypoxia on the Black sea's north-western shelf.

Capet A., Drion R. and Grégoire M.

The main aim of the EU PERSEUS project (Policy-oriented marine Environmental Research in the Southern EUropean Seas) is to assess and preserve the Good Environmental status (GES) of marine waters in the Mediterranean and Black Sea using a pluridisciplinary approach combining data collection, model development and socio-economic analyses.

In this context, we develop a three dimensional coupled circulation biogeochemical model of the Black Sea in order to assess the status, causes and mechanisms of hypoxia on the north-western shelf (BS-NWS) that was severely impacted by eutrophication in the 80s. Model simulations over the last three decades show evidences that hypoxia is still occurring seasonally on a non-negligible area of the bottom waters of the BS-NWS. This important finding (corroborated by the monitoring of local institutes) is in contradiction with the general idea that bottom hypoxia vanished with the reduction after 1992 of river borne nutrient discharge. We found that the overestimation of recovering was due to the use of observations concentrated in areas and months not typically affected by hypoxia.

An index H which merges the aspects of the spatial and temporal extension of the hypoxic event is proposed to quantify, for each year, the intensity of hypoxia as an environmental stressor. In order to provide recommendations for the definition of policies aiming to avoid bottom hypoxia and to preserve the GES of the benthic habitat, a simplified statistical model has been derived to link the H index with the level of nutrients loads discharges by the Danube and specific climate drivers of hypoxia.

This approach allows establishing a cost of the local warming in terms of its impact on hypoxia. We find that the potential increase of water stratification in a global change context may promote the occurrence of seasonal hypoxia and this stresses that the definition of future management scheme of river discharges have to integrate the impact of climate change.

Keywords: hypoxia, modeling, climate change, eutrophication, GES

Oral presentation

Influence of nutrients with different sources on nutrient distribution and primary production in the East China Sea

Wang Y., Guo X., Zhao L. and Zhang J.

With a three-dimensional coupled biophysical model, we investigated the contributions of nutrients from different sources such as terrestrial nutrients from rivers, oceanic nutrients from the Kuroshio and from the Taiwan Strait, and the nutrients by atmospheric deposition, on the nutrient distribution in the East China Sea (ECS), one of the largest marginal seas in the northwest Pacific, and their influences on the primary production there. After validation of the results of a control case that includes all these nutrient sources, we excluded only one source of nutrients and repeated the same calculation as the control case did. The difference between the control case and the calculation without only one source of nutrients suggested that the oceanic nutrient from the Kuroshio contributes most (>60%) dissolved inorganic nitrogen (DIN) to its annual standing stock in the ECS. The contribution of nutrients from rivers and Taiwan Strait were comparable (~10%), while that from atmospheric deposition was lowest. It is also found that the nutrient from the Kuroshio was an essential condition for the formation of subsurface Chl-a maximum layer in the ECS.

Keywords: East China Sea; Oceanic nutrient

Oral presentation

Temporal and spatial variation of seasonal hypoxia off Changjiang Estuary and its relation to physical forcing

Huang D., Ni X., Chen J., Chen Q. and Zhou F.

The Changjiang hypoxic zone is large, forms in summer typically in August each year, and appears to be due to a combination of physical and biogeochemical processes resulted from the estuarine outflows and coastal upwelling intrusion onto the shelf from the East China Sea. Based on the seasonal multi-disciplinary filed surveyed data and buoy monitored data, the spatial and temporal variation of dissolved oxygen and its relation with the oceanic processes were investigated. The observed results show that time evolution of hypoxia is related to background state in early summer, and evolution of stratification during summer, the spatial variation of hypoxia area is related to the pathway of the river plume. Long period, field survey and real-time monitoring are required to understand the causes and effects of hypoxia.

Keywords: Seasonal Hypoxia; Changjiang Estuary

Oral presentation

Phytoplankton community and POC flux in the China Marginal Seas: the Physical-Chemical-Biological Coupling

Huang B., Wang L. and Liu X.

Phytoplankton community composition and its coupling with POC fluxes were determined based on photosynthetic pigment in China marginal seas, East China Sea (ECS) and South China Sea (SCS), through six cruises between 2007-2011, in which effects of mesoscale eddies on phytoplankton and POC fluxes were studied.

For seasonal variations, the biomass was higher in winter and fall than in spring and summer in SCS, while it was highest during spring in ECS. Diatoms dominated community through the year except dinoflagellates were abundant in spring bloom in ECS, meanwhile prasinophytes and haptophytes_8 increased in fall and winter at shelf in ECS. The *Synechococcus* and *Prochlorococcus* were abundant only in the warmer season, especially in the region affected by the Kuroshio in ECS.

The biological pump efficiency (ThE) was mainly between 2~10%, which was higher in winter in ECS and in summer in SCS. The POC fluxes were logarithmic positively with diatoms biomass both in ECS and SCS, although it had no correlation with the total phytoplankton biomass. There was spatial difference on relationship between POC fluxes and phytoplankton groups, POC fluxes were significantly positive correlated with diatom contribution at coast and shelf ($p < 0.010$) while it was negative at basin ($p < 0.001$) in SCS. Furthermore, the POC fluxes were significantly positive correlated with percentage of prasinophytes and haptophytes_8 ($p < 0.010$) in basin of SCS.

The mesoscale eddies had significant impact on phytoplankton biomass, community composition and the POC fluxes in the SCS. For the cyclonic eddy (CE), the surface TChl a biomass was promoted by 2.6-fold in the eddy center, although it was almost equivalent in the term of water column integration. The phytoplankton community was primarily contributed by diatoms, prasinophytes, and *Synechococcus* at deep chlorophyll maximum layer (DCML) within the eddy, while it was less by haptophytes_8 and *Prochlorococcus*. So we assumed that there was a gently continuous nutrient supplied by the doming of isopycnal within the eddy while the increasing of phytoplankton stock was not significant at the DCML, it was remarkable at surface layer even though where the hydrological and nutrient signals were weak. For the anticyclonic eddies (ACEs), the TChl a inventory was almost similar among the three long-lived ACEs (17.647~18.868 mg m⁻²). The TChl a inventory was 20.822±3.026 mg m⁻² at the edge which was 33% and 60% higher than at center and reference, respectively. The most prominent enhancements of biomass at edge was provided by haptophytes_8, with 1.6-fold to the center and 2.2-fold to the reference. The second dominant group, *Prochlorococcus*, had a 50% higher in biomass at edge comparing to reference, and was mediacy at center. The status of higher biomass at ACEs' edge but higher export at center might be the combined results of vertical convection and lateral transport. Diatoms could be responsible for the ~50% enhancement in bSiO₂ flux at center through lateral transport from edge. The positive correlation between POC flux and haptophytes_8 biomass at edge implied their importance in particles export.

Keywords: Phytoplankton, POC flux, mesoscale eddy

Oral presentation

Can enhanced anthropogenic nutrient loading induce high POC export in the East China Sea?

Hung C.-C.

Recent research has shown that enhanced anthropogenic nutrient may have triggered phytoplankton bloom in the coastal ocean, but it is unclear if particulate organic carbon (POC) export production is increased the East China Sea (ECS). In this study, concentrations of POC and rare earth elements (REEs), POC fluxes, and primary production (PP) were measured in both suspended and sinking particles in the ECS in summer 2007 or 2013. In both years, higher and lower concentrations of POC were found in the inner and the outer shelves, respectively. Similar to POC concentrations, higher POC fluxes (up to $7.3 \text{ gC m}^{-2} \text{ d}^{-1}$) were observed in the inner shelf and lower POC fluxes were in the outer shelf, respectively. PP values (up to $3.4 \text{ gC m}^{-2} \text{ d}^{-1}$) had similar distribution patterns to POC fluxes, while some of PP values were lower than POC fluxes, suggesting that contributions of resuspended particles to POC fluxes need to be appropriately corrected. A two end-member model was used to correct effects of bottom sediment resuspension and the highest corrected. The corrected POC fluxes (486 to $785 \text{ mgC m}^{-2} \text{ d}^{-1}$) in the inner shelf could be the minimum value because we could not exactly distinguish the effect of POC flux from Changjiang influence with turbid waters. The results suggest that 91-93% of the POC flux in the inner shelf might be from the contribution of resuspension of bottom sediments rather than from the actual biogenic carbon sinking flux. Besides using POC data on a two end-member model, a similar method was used in estimating particle resuspension based on REE data in suspended particles and sediments. The results show that 60% of POC flux might be from the resuspension of bottom sediments in the inner shelf. In other words, the corrected POC flux based on REEs approach in the inner shelf is $1800 \text{ mg C m}^{-2} \text{ d}^{-1}$ which is much higher than that ($785 \text{ mgC m}^{-2} \text{ d}^{-1}$) based on POC approach. The difference between POC method and REEs method could be the former method ignoring biological degradation of sinking particles. Overall, our results suggest that the increased anthropogenic nutrient loading in the inner shelf might enhance POC export production in the ECS based on a derived-REEs two end-member model.

Keywords: POC flux, PP, East China Sea

Poster presentation

Distributions and vertical fluxes of dissolved and particulate organic carbon in the northern South China Sea

Hung J.J., Tsai L.S., Wang S.M. and Chung Y.-C.

Biogeochemical responses of the surface ocean to seasonal and external-forcing changes are evaluated through distributions and vertical fluxes of dissolved and particulate organic carbon in the northern South China Sea (NSCS). Distributions of dissolved and particulate organic carbon reflect the oceanographic responses to the Kuroshio intrusion, terrestrial inputs and monsoon changes. Particle fluxes vary spatially and temporally and are apparently controlled by physical and biogeochemical processes related to terrestrial inputs, monsoon and special events. Seasonal organic fluxes match roughly with seasonal primary productivity. Both biogenic and lithogenic fluxes were generally higher during the northeast (NE) monsoon season than during the southwest (SW) monsoon season. Particularly high particle and lithogenic fluxes below the surface layer near Taiwan Island may be derived from earthquakes occurring at southern Taiwan. Typhoons appear to induce high primary production and produce high surface C_{org} fluxes. Fluxes decrease generally with depth for biogenic components (OM, carbonate, opal) but increase with depth for lithogenic components (Al₂O₃). The rain ratio (C_{org}/C_{inorg}) also appears to be greater (>1) in those shallow traps closer to the Taiwan Island. Most lithogenic materials appear to be derived from lateral transport below the surface layer, and the deep fluxes show a decrease with distance away from the Taiwan Island. Carbonate dominates the biogenic fluxes in the upper layer and may play as the major ballast in the transportation of biogenic materials through the water column. Fluxes of C_{org} range from 0.69 to 77 mg m⁻² d⁻¹, which are closely correlated with the fluxes of opal (0.94-133 mg m⁻² d⁻¹) and carbonate (4.6-293 mg m⁻² d⁻¹). However, different modes of correlations exist between C_{org} (or carbonate) fluxes and lithogenic fluxes, supporting the various strengths in the lateral fluxes of lithogenic materials for different locations of traps. Although the downward flux of DOC is smaller than the sinking flux of C_{org}, its magnitude constitutes a significant flux of total organic carbon transported through the depth of 150m. The NSCS reveals a variable efficiency in drawing down CO₂ and transporting materials through water columns in different spaces, monsoon seasons and special events.

Keywords: Downward fluxes of DOC and POC

Poster presentation

A numerical experiment on the influence of the Changjiang River Discharge on the lower trophic ecosystem in the Yellow and the East China Seas

Kang H.-W., Kim H., So J.K., Butenschon M. and Allen I.

The Changjiang (Yangtze) River is the third-longest in the world and the longest river in Asia. Its discharging volume is controlled by the natural variability of the precipitation as well as the human interventions such as the Three Gorges Dam which was completed and fully functional in July, 2012. In this study, we compare three solutions of the lower trophic ecosystem responding to the Changjiang River Discharge (CRD) using the high-resolution coupled physico-biogeochemical ecosystem model based on POLCOMS-ERSEM. The model simulated with the half of annual mean CRD for 10 years (1992 - 2001) after the three year spin-up and the final year (2001) solution is diversified in three different cases in conjunction with CRD forcing as 1) the climatological monthly varying river discharge, 2) yearly steady discharge (no seasonal variation) with the half of annual mean climatological discharge rate as it was, and 3) no Changjiang river discharge at all.

The most prominent differences among the solutions appear following the Changjinag Diluted Water (CDW) path centered in the northern border of the East China Sea adjacent to the Yellow Sea and its influences reach up to the East Sea (Sea of Japan). Three areas in the CDW path and two places out of the CDW path (one is in the central Yellow Sea and the other is in the southern East China Sea) are chosen and compared to investigate the influence of the CDW volume discharge on the lower trophic ecosystem. In the CDW path, the supply of surface nutrients from the CDW is crucial during the summer while it is negligible during the winter when the vertical mixing drives the surface nutrients from the bottom. The response time for the CRD forcing, in general, is delayed as the place in the CDW path is located far from the river mouth. The most influenced functional groups are the pico-phytoplankton and the meso-zooplankton in context with the abundance change and the peak blooming time.

It is noteworthy that the Southern East China Sea is affected by the CRD especially for the nutrients supply in summer but the phytoplankton and zoo plankton abundance and the phenology are not much changed except for the pico-plankton bloom peak in May is decreased as CRD increased. It is also remarkable that the influences of the CRD amount and seasonality are negligible on the lower trophic ecosystem in the central Yellow Sea.

Keywords: Changjiang River, Lower Trophic Ecosystem Model

Poster presentation

Spatio-temporal dynamics of biogeochemical processes and air-sea CO₂ fluxes in the Western English Channel based on two years of FerryBox deployment.

Bozec Y., Marrec P., Cariou T., Latimier M., Macé E., Morin P. and Vernet M. Presented by Liu K.K.

The constraint of air–sea CO₂ fluxes and their variability at various time and spatial levels remain a central task in global carbon and climate studies. A global sea surface carbon observing system is needed to unravel inorganic carbon dynamics in coastal ecosystems. Such an observing system would rely on Voluntary Observing Ship (VOS) and time-series measurements of the different parameters of the CO₂ system in seawater for various coastal ecosystems. In this respect, the global estimate and the dynamics of air-sea CO₂ fluxes in coastal ecosystems would be improved by better constraining variations due to processes occurring at daily to inter-annual scales. Further, measurements of the carbonate system parameters will be essential tools to monitor the long-term modification of coastal ecosystems under ocean acidification (OA).

In the framework of the CHANNEL project, a FerryBox system was installed in January 2011 on a Voluntary Observing Ship (VOS), which crossed the Western English Channel (WEC) between Roscoff (France) and Plymouth (UK) up to three times a day. The two years of deployment of the FerryBox provided new insights into the dynamics of air-sea CO₂ fluxes in the contrasted ecosystems of the WEC. The study of short time-scale dynamics of air-sea CO₂ fluxes revealed that an intense and short (less than 10 days) summer bloom in the nWEC contributed to 29% of the CO₂ sink during the productive period, highlighting the necessity for high frequency observations in coastal ecosystems. An extraction of day/night data at 49.90°N showed that the mean day-night differences accounted for 16% of the mean CO₂ sink during the 5 months of the study period implying that the diel biological cycle was also significant for air-sea CO₂ flux computations. Further, the two years of FerryBox records revealed important inter-annual dynamics of the carbonate system due to contrasting environmental conditions. Long-term deployments of FerryBoxes are challenging in terms of maintenance and long term funding, but critical to assess anthropogenic forcings (e.g. ocean acidification, eutrophication) on coastal ecosystems in the context of climate change.

Keywords: air-sea CO₂ fluxes, ferrybox, coastal seas

Poster presentation

Spatio-temporal dynamics of air-sea CO₂ fluxes in Gulf of Lion (Mediterranean Sea)

Bozec Y., Cariou T., Collin E., Durand A. Macé E., Marrec P., Thuillier D. and Vernet M.
Presented by Liu K.K.

Over the past decade, the coastal oceans have been the focus of several studies highlighting the key role of these ecosystems in the global budget of air-sea CO₂ fluxes. The spatial variability in air-sea CO₂ fluxes is large from one coastal ecosystem to the other and it was recently proposed to classify continental shelves as sinks and near-shore ecosystems as sources of atmospheric CO₂. However, the latest estimates of air-sea CO₂ fluxes in coastal ecosystems are subject to large uncertainty. At present, the lack of sufficient data is the major limitation in the quantification of the spatial and temporal variability of these CO₂ fluxes in coastal environments. This lack of data is even more relevant in coastal ecosystems impacted by estuarine plumes. While there is an emerging agreement on the role of inner estuaries as source of CO₂ to the atmosphere, estuarine plumes (e.g. outer estuaries) can either act as sources or as sinks for atmospheric CO₂. To accurately constrain the present impact of estuarine plumes in global air-sea CO₂ fluxes, additional investigations must be carried out in a greater diversity of ecosystems.

The air-sea CO₂ fluxes in Mediterranean coastal ecosystems impacted by estuarine inputs have been particularly poorly investigated. The Gulf of Lion is a coastal ecosystem considerably impacted by freshwaters inputs from the largest estuary surrounding the Mediterranean Sea namely the Rhône. In the framework of the MERMEX-CARBORHONE project, we investigated the processes controlling the air-sea CO₂ fluxes from the inner estuary to the estuarine plume located within the 1500 m isobath of the Gulf of Lion. Our approach relied on four seasonal cruises carried out in 2011 and 2012. In the present paper, we provide a first assessment of the processes controlling the carbon dioxide system in the extremely heterogeneous coastal ecosystem “Rhône estuary/Inner Gulf of Lions”. This first assessment will constitute a basis for a future understanding of the carbon dioxide system alteration under global change.

Keywords: air-sea CO₂ fluxes, Mediterranean Sea

Poster presentation

Coupled nitrogen and oxygen isotope measurements of nitrate in the Yellow Sea: a tracer for nitrogen cycling

Liu S.M., Altabet M.A., Larkum J., Zhang G.L. and Song G.D.

Nitrogen biogeochemistry in the Yellow Sea was addressed using nutrient concentrations and dual isotopes of nitrate and other nitrogen species. They provided integrative constraints on the origins and rate of the dissolved nitrogen in early spring water which fuels the spring bloom. The $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ of nitrate in the Yellow Sea show wide range from 6.1 to 12.6‰ and from 6.9 to 14.2‰ with averages of 8.0‰ and 10.4‰, respectively. In general, both the $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ values were higher in the northern part than in the southern part of the Yellow Sea and had a larger range in surface waters than in near-bottom waters. Nitrate N and O isotopes show continental shelf characteristics related to active recycling of nitrogen and nitrogen assimilation, and the Yellow Sea Warm Current water far derives from the Kuroshio Subsurface Water trait. The $\delta^{18}\text{O}:\delta^{15}\text{N}$ ratio was 1.5, similar to that in the Changjiang and within the range of other natural systems of 1.3-2.0. Nitrogen budget indicates the very importance of nutrient regeneration in sediment for nitrate and atmospheric deposition contributes the most ammonium load. Replete- $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ of nitrate and high $\delta^{18}\text{O}$ relative to $\delta^{15}\text{N}$ developed in the Yellow Sea mainly derived from nitrification, atmospheric deposition, and active recycling of nitrogen.

Keywords: isotopes, nitrate, Yellow Sea

Oral presentation

Effects of the shelf circulation in the dispersion of terrestrial inputs in the Northwest Atlantic Ocean

Narvaez D.A., Hofmann E.E., Wilkin J., Friedrichs M.A.M. and Tian H.

A 5-year hindcast (2004 to 2008) from a ROMS-based biogeochemical-circulation model, forced with river discharge inputs from the Dynamic Land Ecosystem Model, was used to investigate controls on the dispersion of material discharged from rivers and estuaries along the U.S. eastern continental shelf. Passive tracers released in 15 major rivers throughout the region represent inputs of terrestrial material, such as nutrients. At short time scales, surface tracers respond to wind field variations. Seasonally, the dispersion of the rivers and estuaries discharge change from northward to southward during May-June. Interannual variability during summer months is generally associated with presence or absence of a warm-core eddy in the northwestern Mid-Atlantic Bight. The anticyclonic eddy circulation tends to disperse the tracer plumes northward within a few days. The simulated tracer distributions showed little connection between the northern and southern shelf regions and across the shelf, with most of the exchange localized off Cape Hatteras. These simulations provide insights into the potential effects of the shelf circulation in the dispersion of nutrients (and other materials) coming from rivers, which has implications for developing nutrient budgets

Keywords: River discharge, continental shelf, biogeochemical cycles

Oral presentation

Impacts of anthropogenic stressors and climate change on the Black Sea biogeochemistry and ecosystem

Oguz T., Saligoglu B., Fach B., Arkin S.

The Black Sea experienced the community-wide trophic cascades under concurrent impacts of eutrophication and overfishing together with the invasive gelatinous predator species and strong decadal climatic changes. Starting in the early 1990s, the northeastern region pelagic food web structure exhibited negligibly low fish stocks even at the lowest ecological level of small pelagics as well as low-to-moderate gelatinous populations and similarly degraded benthic structure limited mostly to the polychaeta population. This pelagic ecosystem structure therefore appears to be under low predator pressures as further evident by the gradually increasing mesozooplankton biomass during the years. The ecological degradation remained to be even more severe in the northwestern shelf region where the pelagic food web structure is primarily controlled by jellyfish and the benthic community is dominated by polychaeta. The southern basin is however relatively healthy and able to maintain anchovy fishery with weak gelatinous predation. The level of degradations within the Black Sea regional food webs in terms of fish biomass/landings, jellyfish/mesozooplankton abundance ratio, pelagic and benthic communities alternations may be considered rather exceptional cases among large marine ecosystems. Complexity of trophic interactions, the highly nonlinear character of the foodweb structures and their simultaneous controls by exogenous factors and indigenous mechanisms offer a truly challenging task for a model-oriented management efforts towards their rehabilitation and recovery. A continuous trend of decadal scale climatic warming appears to introduce a further complexity on the ecosystem dynamics.

Keywords: Black Sea, regime shift

Oral presentation

Science to Governance in marine LMEs: a case study of ecosystem functioning in the Mozambique Channel and the possible mechanisms for addressing management needs related to the impacts of climate change

Vousden D. and Roberts M.

Translating scientific results and accumulated knowledge into management actions and responses remains one of the primary challenges and constraints to effective governance of marine ecosystems and the oceans per se. Traditional scientific methodologies for estimating reliability of data and drawing justifiable conclusions based on confidence intervals are undoubtedly still 'best practice'. In the absence of such proof, the precautionary principle is an essential foundation from which to underpin all management approaches. However, more recently there has been a move to adopt a more dynamic management approach based on comprehensively peer-reviewed 'weight-of-evidence' which, although not supported by the higher 95-99% probabilities, can provide robust evidence and justification for trends arising from data. With sufficient peer consensus acknowledging these trends, management advice and even policy guidelines can be presented to national and regional decision-makers to allow them to take appropriate actions for adaptive/preventive management that can address actual or potential impacts and threats (particularly at the vulnerable human community level) in a timely manner. One case study presently being explored as a pilot 'trial' for such an approach is that of the Mozambique Channel, the ecosystem functions therein, and the potential impacts of climate change. Recent results from a large multidisciplinary research program (MESOBIO) has shown that the Mozambique Channel is an area of intense mesoscale eddy activity generated by the interaction of the South Equatorial Current (SEC) with the landmass of Madagascar. The energy of this complex eddy field creates vertical movement of nutrients from depth into the photic layer of the channel waters regulating primary and secondary production — and ultimately, higher levels of the ecosystem. The turbulent energy varies on both intra- and inter-annual time scales related to changes in the equatorial wind patterns over the Indian Ocean causing a "spin up" and "spin down" of the ecosystem. Future eddy-related research within and adjacent to the Mozambique Channel, along with the biological implications arising from these studies, should now be focused on defining mid-to long-term trends vis-à-vis implications for communities dependent on the goods and services within this ecosystem. A comprehensive understanding of bio-physical processes in the region is necessary to monitor the state and trend of the ecosystem and implement public policies aiming at sustaining livelihood for coastal communities and preserving biodiversity in the most sensitive areas. The Mozambique Channel remains a unique natural laboratory for such an endeavour.

Keywords: Mozambique Channel, ecosystem, science-to-governance

Oral presentation

For resolving Kuroshio Paradox and sustainable use of ecosystem services: The Study of Kuroshio Ecosystem Dynamics for Sustainable Fisheries (SKED)

Saito H.

Kuroshio is a warm western boundary current of the North Pacific flowing along continental shelf of Taiwan and the Japanese archipelago. The meaning of “Kuroshio” in Japanese is “black current” which is from dark blue water color (i.e., low phytoplankton biomass) different from greenish (i.e., high phytoplankton biomass) coastal water. In spite of the oligotrophy, various fishes and squids uses the Kuroshio region as spawning and nursery ground. These Kuroshio species contribute to 58% of fisheries landing in Japanese water. I named this inconsistency of high fisheries production in oligotrophic water as Kuroshio paradox. To resolve the Kuroshio paradox, interdisciplinary research project “The Study of Kuroshio Ecosystem Dynamics for Sustainable Fisheries” (SKED) was launched in 2011. Several mechanisms supporting high fisheries productivity in the oligotrophic Kuroshio region have been found in the SKED. Nutrients supplied to euphotic zone by various physical mechanisms, such as isopycnal mixing, strong turbulence along the axis, coastal water intrusion, etc., support phytoplankton production dominated by nano-phytoplankton. The primary production is transferred to calanoid copepods (e.g., Paracalanus, Calanus) through grazing food chain or poecilostomatoid copepods (e.g., Oncaea, Corycaeus, Sapphirina) through gelatinous filter feeding zooplankton such as appendicularians and doliolids. Continuous production of the prey zooplankton which species composition shows seasonal succession responding to nutrient supply makes the Kuroshio region for good nursery ground of various fish species. Fisheries production in the Kuroshio region showed long-term variation depending on the environmental change. A part of the variation is assumed due to increasing fishing pressure. For the sustainable and wise use of fisheries production, understanding the mechanisms of ecosystem responses to natural and anthropogenic pressure is essential. In the presentation, fisheries impacts on ecosystem structure obtained from modeling approach will be presented.

Keywords: Kuroshio, ecosystem services, nutrient, zooplankton, fisheries

Oral presentation

Influences of terrestrial discharges on benthic ecosystem in the East China Sea: eutrophication, hypoxia and low fish diversity

Chang N.-N., Shiao J.-C., Gong G.-C., Kao S.-J.

The East China Sea (ECS) has been greatly impacted by receiving large quantities of particulate organic matters (POM) and inorganic nutrients transported from the Changjiang over the past decades, which reduces fishery resources. This study evaluated potential effects of terrigenous POM and nutrient-induced marine production to the ECS benthic ecosystem by oceanographic surveys, analyzing stable isotopic compositions of phytoplankton, zooplankton, benthic crustaceans and fish. The inshore area of the ECS, corresponding to the prohibited zone for trawling, had extremely high nutrient concentrations and relatively low dissolved oxygen. The diversity index of demersal fish showed significantly negative correlations with nutrient concentrations and positive correlations with bottom-water dissolved oxygen. The inshore area of the ECS was heavily dominated by small-sized fishes, such as Gobiids—*Amblychaeturichthys hexanema* and Apogonids—*Apogon lineatus*, reflecting low survival of most fish species. In contrast, the offshore areas, with lower nutrient concentrations and higher dissolved oxygen, had higher biodiversity. The $\delta^{13}\text{C}$ signals of benthic fish (-19.6‰ to -13.5‰) and crustaceans (-18.9‰ to -15.0‰) were greatly higher than that of terrigenous POM (-25.7‰) and more similar to the $\delta^{13}\text{C}$ values of autochthonous phytoplankton and zooplankton. In addition, $\delta^{13}\text{C}$ of demersal fish assemblages exhibited a seaward decreasing trend with significantly higher values at inshore sites. The significantly positive correlations between concentrations of chlorophyll a and nutrients versus fish $\delta^{13}\text{C}$ provided evidences for the uptake of pelagic algal blooming materials by benthic consumers. The oceanographic survey and isotopic data suggested that inorganic nutrients nourish benthic consumers in the ECS rather than terrestrial POM. Terrestrial discharges induce eutrophication and subsequent hypoxia is responsible for the limited recovery of fishery resources in the trawling prohibition area of the ECS.

Keywords: Eutrophication, benthic ecosystem, fish community

Oral presentation

Session F4: Impacts of anthropogenic stressors and climate change on biogeochemistry-ecosystem in continental margins and feedbacks to earth system and society: challenges and solutions

Oral Presentations

Wednesday 25 June, 11:00-12:30 Parallel session 4

Chairs: Zouhair Lachkar and Kay Emeis

Room D7

Time	Presenter	Title
11:00-11:15	Rykaczewski, Ryan	Investigating the upwelling intensification hypothesis using climate-change simulations
11:15-11:30	Schmidt, Martin	Temperature bias in circulation models of the Benguela Upwelling Area and the implications for coupled ecosystem models
11:30-11:45	Mohrholz, Volker	The remote and local physical forcing in the Northern Benguela upwelling system and its impact on the environmental conditions.
11:45-12:00	Escribano, Ruben	The changing oxygen minimum zone and its effects on ecosystem functioning in an eastern boundary upwelling system
12:00-12:15	Rixen, Tim	Benguela Upwelling System: A sink or source of CO ₂ to the atmosphere?
12:15-12:30	Lachkar, Zouhair	The evolution of multiple stressors in the Canary upwelling system over the 21 st century

Wednesday 25 June, 14:00-15:30 Parallel session 5

Chairs: Kay Emeis and Werner Ekau

Room D7

Time	Presenter	Title
14:00-14:15	Turi, Giuliana	Recent climatic trends modulate ongoing ocean acidification in the California Current System
14:15-14:30	Lamont, Tarron	Physical drivers of phytoplankton production in the southern Benguela upwelling system
14:30-14:45	Auel, Holger	Food-web structure and trophic interactions in the northern Benguela upwelling system
14:45-15:00	Ekau, Werner	Physiological characteristics of plankton organisms and their role in ecosystem functioning. Results from GENUS I and II
15:00-15:15	Werner, Thorsten	Contribution of mesozooplankton to the vertical flux of organic carbon in the northern Benguela Upwelling

Session F4: Eastern Boundary Upwelling Systems

		System off Namibia
15:15-15:30	All	Discussion

Poster presentations

Wednesday 25 June, 17:30 Poster Session 2

ID	Presenter	Title
F4.P1	Bohata, Karolina	The microzooplankton community of the northern Benguela Upwelling System
F4.P2	Flohr, Anita	Carbon pumps in the northern Benguela upwelling system
F4.P3	Geist, Simon	Early life history traits of coastal pelagic fish species in the northern Benguela upwelling system - advantage for Cape Horse Mackerel
F4.P4	Hidalgo, Pamela	Physiological responses of zooplankton in the upwelling system in the Eastern South Pacific: effect of the oxygen minimum zone
F4.P5	Junker, Tim	Meridional transport in the Benguela upwelling system and its relation to the wind forcing
F4.P6	Martin, Bettina	Distribution of zooplankton biomass in the northern Benguela Upwelling System
F4.P7	Schukat, Anna	Energy demands of calanoid copepods and pelagic decapods of the Benguela upwelling system and their contribution to active carbon flux
F4.P8	Tim, Nele	Water mass analysis of the Benguela upwelling system referring to the oxygen minimum zone
F4.P9	Lahajnar, Niko	Organic matter cycling in the Benguela Upwelling System: Insights from amino acid biogeochemistry
F4.P10	Brust-Möbius, Juliane	Remote sensing of coccolithophore blooms within filaments of the Benguela upwelling system
F4.P11	Koppelman, Rolf	The gelatinous component of the mesozooplankton community in the northern Benguela Upwelling System
F4.P12	Hagen, Wilhelm	Trophic interactions of calanoid copepods in the northern Benguela upwelling system
F4.P13	Emeis, Kay	Nutrient and CO ₂ dynamics in the northern Benguela Upwelling System

Food-web structure and trophic interactions in the northern Benguela upwelling system

Auel H., Schukat A., Bode M., Hagen W., Moroff N., Koppelman R., Martin B., Werner T., Bohata K., Geist S., Ekau W., Buchholz F., Wasmund N., Schmidt M., Lahajnar N. and the GENUS team

In the framework of the GENUS – “Geochemistry and Ecology of the Namibian Upwelling System” research program, trophic interactions and carbon pathways throughout the food web of the coastal upwelling system are being quantified. In contrast to earlier studies, special focus is given to lower trophic levels in higher taxonomic resolution. Energy demands of various zooplankton taxa, including copepods, euphausiids, decapods and fish larvae, have been quantified with standardized methodology via optode respirometry. Dietary spectra and trophic levels were analyzed by trophic biomarker approaches based on fatty acid composition and stable isotopes (^{15}N , ^{13}C), respectively. All empirical data are assembled for an Ecopath with Ecosim (EwE) food-web model. The EwE model distinguishes between shelf and offshore communities. The conceptual food-web model consists of three groups of primary producers, i.e. diatoms, dinoflagellates, and cyanobacteria, as well as many consumers such as *Calanoides carinatus* as the key herbivorous copepod in the Benguela upwelling system, other copepods, *Euphausia hanseni*, other zooplankton, and pelagic fishes including sardine, anchovy, and horse mackerel. Empirical data show that zooplankton and particularly copepods encompass a wider range of trophic levels from herbivory to secondary or even tertiary consumers ($\delta^{15}\text{N}$ from 4 to 12‰), while anchovy had rather low $\delta^{15}\text{N}$ of about 7‰. Respiration rates and metabolic activities of copepods could be parameterised for the model by an energy budget approach based on ambient temperature, body mass, and activity level. Calanoid copepods consumed $78 \text{ mg C m}^{-2} \text{ d}^{-1}$ in shelf regions and $21 \text{ mg C m}^{-2} \text{ d}^{-1}$ in oceanic regions. Locally, *C. carinatus* could remove up to 90% of the diatom biomass per day. The community consumption of pelagic decapods ranged from $7 \text{ mg C m}^{-2} \text{ d}^{-1}$ to $>20 \text{ mg C m}^{-2} \text{ d}^{-1}$ with highest values in the northernmost part of the study area. Overall, pelagic decapods apparently play a more prominent role in the northern Benguela ecosystem than previously assumed and may exert a substantial predation pressure on calanid copepods. GENUS results emphasize that the trophic interactions within zooplankton and lower trophic levels are more complex than just linking primary producers with pelagic fish and should be taken into account in the process of developing realistic food-web models of coastal upwelling systems.

Keywords: foodweb, zooplankton, trophic interactions, energy flux

Oral presentation

The microzooplankton community of the northern Benguela Upwelling System

Bohata K., Koppelman R. and Möllmann C.

Microzooplankton are small organisms (up to 200 µm) consisting of Protozoa and Metazoa which are important members of the pelagic food web since they provide a link between primary producers and higher trophic levels. In the past, only few studies on microzooplankton distribution and composition and their position in the food web related to different water masses were conducted in upwelling areas. In our study, we describe for the first time the general abundances of microzooplankton and their occurrence depending on environmental parameters in the Benguela Upwelling System and the community composition with special reference to Tintinnids. Samples were collected during January and February 2011 on an expedition with the research vessel Maria S. Merian as a part of the GENUS (Geochemistry and Ecology of the Namibian Upwelling System) project. Samples were collected on six transects from onshore to offshore off the northern Namibian coast between 26°S and 17°S. The samples were obtained by stratified vertical hauls using a multinet. The distribution of tintinnids indicated higher abundances in slope and offshore areas. The along-shore distribution of tintinnids showed distinct differences in the composition and dominance of some tintinnid species. The northern area was mainly dominated by cosmopolitan species such as *Codonellopsis* sp. and its abundance had a decreasing trend southwards. The centre part of the BUS was dominated by warm-temperate species such as *Epiplocyilis* sp. and *Rhabdonella* sp. and cosmopolitan species such as *Codonella* sp. The southern part at the Lüderitz upwelling cell, was very poor of tintinnids. This area was dominated by warm-temperate species such as *Epiplocyilis* sp. and *Xystonella* sp. This low abundance in this area could be caused by high upwelling event over the year and thereby strong drift from the coast which leads to a lower production. Additionally, there was an apparent pattern in the distribution with increasing tintinnid abundance in the direction from the coast to the open ocean. In this study, we try to classify the detected species in dependence of different water masses and show, that tintinnids could be used as indicators of different water masses.

Keywords: Benguela Upwelling System, Microzooplankton, Tintinnida

Poster presentation

Remote sensing of coccolithophore blooms within filaments of the Benguela upwelling system

Brust-Möbius J.

Field studies have shown that high remote sensing reflectances of water masses occurring offshore Namibia can be linked with the presence of coccolithophores, whose suspended calcareous shells enhance light scattering. The marker pigment 19-hexanyloxifocuxanthin was determined in the entire area but coccolithophore blooms were observed only sporadically, visible by milky turquoise water masses in satellite images. The blooms were followed for several days to weeks which should be linked to persistent stable filaments with a limited vertical extent. This is one main condition because they are able to develop in high sun irradiation. A stable shallow surface layer and moderate wind velocities of around 5 m s^{-1} facilitate the evolution of coccolithophore blooms. High nitrate-to-phosphate ratios and depleted silicate concentrations are starting conditions for coccolithophore blooms. It is assumed that coccolithophores follow preceding typical phytoplankton successions of diatoms and dinoflagellates evolving in upwelling filaments of the Benguela system. As part of the filament development these blooms contribute to the energy and matter transport from coast to open ocean.

The analysis of daily MODIS Terra and Aqua satellite images of the years 2003 to 2013 reveal that the frequency of coccolithophore blooms decreases from south to north outside the active upwelling cells off the Namibian coast. Their occurrence varies seasonally and interannually and their duration is in the range of several days to a few weeks. Regarding the number of days with coccolithophore blooms visible in satellite images, the months with the highest number of days are December to April, the season with lowest wind speeds and weakest upwelling. From June to September the lowest numbers of days with blooms can be observed, although high wind speeds intensify upwelling during these months. Most of the blooms develop in the offshore area of Walvis Bay.

Time series of satellite data will be presented as examples for persistent coccolithophore blooms. Their optical properties will be analysed and the spatial and temporal development will be presented with regard to bloom-controlling physical parameters (e.g. wind, sea surface temperature). The acquired data will also serve as a basis for ecosystem model validation.

Keywords: coccolithophores, remote sensing, upwelling, filaments

Poster presentation

Physiological characteristics of plankton organisms and their role in ecosystem functioning. Results from GENUS I and II

Ekau W., Auel H., Bode M., Bohata K., Buchholz F., Geist S., Hagen W., Horaeb R., Hünnerlage K., Jung A.S., Koppelman R., Kreiner A., Kunzmann A., Michalek K., Michalowski K., Martin B., Schukat A., Verheye H.M. and Werner T.

The goal of the GENUS project (Geochemistry and Ecology of the Namibian Upwelling System) is to analyse the interrelationships between climate change, oceanic nutrients, greenhouse gases and the ecosystem structure in the coastal upwelling area off Namibia. The biological/ecological work package focused on the structure of the Northern Benguela Upwelling System (NBUS) and its energy flows under changing environmental conditions. Physiological constraints and adaptations were detected in several taxonomic groups investigated within the project, such as several copepod species, euphausiids and fish larvae. Temperature and oxygen distribution in the water column were identified as main drivers in modulating the distribution and ecology of many species. The extension and position of the Oxygen Minimum Zone (OMZ) seems to have a significant impact on the life cycles, vertical distribution and trophic condition of various species. In copepods we find a variety of adaptation mechanisms. While some species avoid the OMZ, others use it for resting and predator avoidance during daytime. Such vertical migrations contribute significantly to vertical carbon flux. The same holds true for decapods ($4.4 \text{ mg C m}^{-2} \text{ d}^{-1}$). Respiration rates of 16 copepod species were determined to average $54.6 \pm 32.8 \text{ ml O}_2 \text{ d}^{-1} \text{ gDM}^{-1}$. *Calanoides carinatus* diapausing C5 stages reduced respiration at depth by 82% compared to surface activity. Further adaptations were found in euphausiid species: While *Euphausia hanseni* is capable to use the OMZ as a retreat by reducing its metabolic activity at lower temperatures and unfavourable trophic conditions, *Nematoscelis megalops* generally maintains a low level metabolism adapted to a constant life in the OMZ, and avoids crossing the thermocline. Special features of early life stages of *Trachurus capensis*, the fish species actually showing highest commercial landings, were analysed to elucidate their potential advantages in life performance, compared to other small pelagic species such as sardines or anchovies. The species showed short-term hypoxia tolerance down to 30% oxygen saturation and even survived 10% saturation. Combined with the ability to switch from smaller to larger copepod prey and to surpass vulnerable early stages much faster than competitor species, this could explain the dominance of *Trachurus capensis* in the NBUS. In addition, competitors and predators of fish larvae such as jellyfish or chaetognaths showed little or no response to low oxygen concentrations gaining advantage over e.g. sardines and anchovies. Isotope analyses of various pelagic species and their food revealed a complex picture of the trophic levels of species including developmental stages and provide the basis for trophic flow models. The results will also serve to calibrate carbon dynamics and nutrient flux models that were developed in another GENUS work package. Data will be compared with nutrient distribution patterns and dynamics that may influence primary production and impact zooplankton distribution and higher trophic levels such as fish, seabirds or mammals. Results clearly show that continuing ocean warming coupled with expansion of the OMZ may alter horizontal and vertical distribution of species and the food web structure of the ecosystem.

Keywords: Benguela Current, OMZ, Pelagic Ecosystem, Physiology
Oral presentation

Nutrient and CO₂ dynamics in the northern Benguela Upwelling System

Emeis K.-C., Rixen T., Flohr A. and Lahajnar N.

Upwelling is a physical valve that regulates the ascent of cold sub-thermocline waters to the sea surface and links the deep ocean CO₂ reservoir with the atmosphere. Most, if not all, upwelling systems are sources of atmospheric CO₂ on time scales of days to seasons. At the same time, upwelling brings nutrients to light and fosters high primary productivity. Thus CO₂ is recaptured by photosynthesis and exported to deeper waters via the biological pump. In stoichiometric terms, the CO₂ budget between degassing and assimilation/particle export should be closed at annual and longer time scales, but the oxygen regime plays a decisive role on masses and ratios of nutrients available for the biological pump.

In the northern Benguela upwelling system offshore Namibia, two branches of the South Atlantic intermediate water mass well up over the shelf and upper continental margin. Both originate from the intermediate water formation area in the Subantarctic Confluence region of the South Atlantic, but have different travel times, ages, and nutrient, CO₂ and oxygen inventories. The older South Atlantic Central Water characterized by low oxygen content (paired with high nutrient and CO₂ inventories from recycling of organic matter) is frequently overwhelmed by oxygen demand from re-mineralisation of organic matter produced over the shelf from upwelled nutrients. Analyses of nutrient concentrations of surface waters in high temporal and spatial resolution during 3 expeditions illustrate an underlying pattern of low N:P ratios in modified upwelling water (<16), albeit with extreme variability in space and time. While this suggests massive losses of reactive N (nitrate, ammonium) of 2.5 Tg N per year, we quantified the loss of reactive N to denitrification (by using stable nitrate isotopes) to only 0.25 Tg per year.

The seeming N-loss implied by low water-column N:P ratios on the other hand may just as well be a gain of phosphate from reflux across anoxic/suboxic sediment-water interfaces coinciding with the extent of organic-rich diatomaceous oozes. This notion is underscored by C:N:P:O₂ ratios of 106:16:1.8:138 observed over the O₂-poor shelf. The low C:P ratio on the Namibian shelf point to phosphate pore water effluxes more than denitrification, which viewed from the angle of C:P ratios is subordinate. But a study of pore water concentrations and analyses of diffusive effluxes at 34 stations on shelf and upper slope showed that the averaged mass fluxes of N and P from the 15,000 km² covered by the mud belt were less than 4,500 mol P d⁻¹ and 30,000 mol N d⁻¹, respectively, which explains only a fraction of the N:P imbalance in the northern sub-system. Clearly, the nutrient balances and therewith the CO₂ budget between degassing and assimilation/particle export in the northern Benguela upwelling system are far from closed.

Keywords: Benguela, upwelling, nutrient balance, CO₂ balance

Poster presentation

The changing oxygen minimum zone and its effects on ecosystem functioning in an eastern boundary upwelling system

Escribano R., Frederick L., Valdes V and Aníñir K.

Variability in the distribution of the Oxygen Minimum Zone (ZMO) in the coastal upwelling zone off the Humboldt Current may affect plankton distribution, and this can have important consequences for trophic interactions and the C-transfer through the pelagic food web. In the northern Humboldt Current off Chile the analysis of hydrographic data shows a significant trend of the OMZ as to become shallower from about 60 m to ca. 20 m in average through the last 30 years. This process may provoke plankton become more aggregated in the upper normoxic layer. Highly aggregated plankton intensifies the biological interactions, including grazing, and hence increase the efficiency of C-transfer. We assessed hydrographic data bases from 1980 to present at northern Chile and showed that both the mixing layer and the oxycline have gradually become shallower in the upwelling zone. We also conducted microcosm experiments with natural live assemblages of zooplankton feeding on their natural food resources upon variables, under simulated levels of microplankton aggregation, as a food resource for grazers. Measurements of community respiration rates (oxygen consumption) showed that metabolic rates of zooplankton can significantly increase with food concentration upon more intense feeding. The acceleration of metabolic and feeding rates suggests that under conditions of highly aggregated plankton, C could be more efficiently transferred among trophic components, and thus favoring a faster C recycling in the upwelling system. These findings may further suggest that the gradual increase in shallowness of the OMZ due to more intense upwelling can have a significant impact in nutrient recycling and its dynamics with uncertain consequences for the functioning and productivity of the upwelling ecosystem.

Keywords: Humboldt-Current, Upwelling, OMZ, Plankton, C-flux

Oral presentation

Carbon pumps in the northern Benguela upwelling system

Flohr A., van der Plas A. and Rixen T.

The northern Benguela upwelling system (NBUS) is one of the ocean's most productive regions characterized by high turnover rates of carbon sustaining a pronounced subsurface oxygen minimum zone. Associated high organic carbon sedimentation rates indicate an efficient sequestration of CO₂ by the organic carbon pump. In order to investigate impacts on the carbonate counter pump, the second biologically driven carbon pump in the ocean, dissolved inorganic carbon (DIC), the stable carbon isotopic composition of DIC ($\delta^{13}\text{C-DIC}$), total alkalinity (TA) and the pCO₂ was measured in the NBUS off Namibia during a number of research cruises. Our results show that the decomposition of organic matter mainly produced by diatoms controls the distribution of oxygen and DIC in the water column and lowers the calcite saturation state Ω_{calcite} in the ascending sub-thermocline waters. The low Ω_{calcite} reduces the carbonate production relative to the high formation and export of organic matter on the Namibian shelf. The dissolution of carbonate, which further reduces the sedimentation of carbonates on the Namibian shelf, occurs in the bottom water where Ω_{calcite} is < 1.3 . This shows that an extremely efficient organic carbon pump further enhances the CO₂ uptake of the biological pump by lowering the carbonate formation in surface waters and the carbonate sedimentation by keeping Ω_{calcite} low within the NBUS.

Keywords: carbon cycle, carbonate saturation

Poster presentation

Early life history traits of coastal pelagic fish species in the northern Benguela upwelling system – advantage for Cape Horse Mackerel

Geist S., Ekau W., Eggert A., Kunzmann A. and Michalek K.

The planktonic larval stages of marine fish are generally characterised by low survival rates, which are caused by multiple factors making the recruitment process a bottleneck for the development of adult stocks. Among those factors are hydrodynamic processes such as advection from favourable onshore feeding grounds, biological interactions such as predation and starvation and physiological constraints of the fish related to e.g. water temperature and dissolved oxygen concentrations.

Here we compare larval traits of three coastal pelagic species - sardine (*Sardinops sagax*), anchovy (*Engraulis encrasicolus*) and cape horse mackerel (*Trachurus capensis*) - gained from samples taken in the northern Benguela Upwelling System (nBUS) during the GENUS project (Geochemistry and Ecology of the Namibian Upwelling System). The nBUS has experienced a regime shift from a “sardine -dominated” state to the present state where *T. capensis* is the only remaining coastal pelagic species of greater economic importance. Some of the most important environmental influences, discussed as triggers, are a warming of the system, the expansion of oxygen minimum zones and a change in zooplankton composition, e.g. increased abundance of small cyclopoid copepods (*Oithona* sp.). Based on results of their spatial distribution, feeding ecology, energy demand, nutritional condition and hypoxia tolerance capacities we assume that *T. capensis* larval traits are more robust than those of *S. sagax* and *E. encrasicolus* larvae.

The highest larval densities in all three species were encountered during austral summer. *T. capensis* and *E. encrasicolus* larvae showed a wider spatial distribution than *S. sagax*, occurring in significant numbers also in the northern part of the nBUS, where high water temperatures occur more frequently during austral summer compared to its central part. Consequently, *T. capensis* and *E. encrasicolus* larvae are classified as eurytherm. All three species fed mainly on copepods. *T. capensis* larvae were successful predators of a wide taxonomic range, with the small-sized *Oithona* sp. and *Oncaea* sp. contributing significantly to their diet. In contrast, *S. sagax* and *E. encrasicolus* larvae appeared to be less successful predators with a higher importance of copepod nauplii and diatoms as food source. Comparing seasons, nutritional condition was highest during summer in all three species. However, at extremely high densities, *S. sagax* larvae had a significantly reduced nutritional condition. In the two eurythermal species, the fatty acid content of *T. capensis* larvae was generally higher than that of *E. encrasicolus* larvae. Respiration experiments showed that *T. capensis* juveniles are extremely tolerant to short-term hypoxia exposure and also larvae seem to be comparatively robust (Geist et al., 2013). Comparing between species, enzymatic activities related to anaerobic metabolism were higher in *T. capensis* larvae indicating a higher potential to cope with hypoxic conditions. A conceptual model is composed, how larval traits influence the differential recruitment success of *S. sagax*, *E. encrasicolus* and *T. capensis* under the prevailing environmental conditions in the NBUS. By this it sheds some light on the black box of “density dependent processes” in fish recruitment theory.

Keywords: coastal pelagics; early life history traits
Poster presentation

Trophic interactions of calanoid copepods in the northern Benguela Upwelling System

Hagen W., Schukat A. and Auel H.

Life-cycle adaptations, dietary preferences and trophic levels of calanoid copepods from the northern Benguela Current off Namibia were determined via total lipid levels, lipid class compositions, marker fatty acids and stable isotope analyses, respectively. Trophic levels of copepod species were compared to other zooplankton taxa and top consumers. Lipid class analyses revealed that three of the dominant calanoid copepod species stored primarily wax esters, four accumulated triacylglycerols and another three species were characterised by high phospholipid levels, probably reflecting different life strategies. The two biomarker approaches (via fatty acids and stable isotopes) revealed a wide spectrum and complex pattern of trophic positions for the various copepod species, but also highlighted the dietary importance of diatoms and dinoflagellates. The key species *Calanoides carinatus* and *Nannocalanus* minor occupied the lowest trophic level (predominantly herbivorous) corresponding to high amounts of fatty acid markers for diatoms (e.g. 16:1(n⁻⁷)) and dinoflagellates (e.g. 18:4(n⁻³)). These two copepod species represent the classical link between primary production and higher trophic levels. All other copepods were omnivorous or carnivorous, hence belonged to secondary or even tertiary (some deep-sea copepods) consumers. The calanoid copepod species cover the entire range of $\delta^{15}\text{N}$ ratios, as compared to $\delta^{15}\text{N}$ ratios of all non-calanoid taxa investigated, ranging from filter-feeding salps to adult predatory fish. These data emphasise that the trophic roles of calanoid copepods are far more complex than just interlinking primary producers with pelagic fish. Although quite challenging, this should also be considered in the process of developing realistic food-web models of coastal upwelling systems.

Keywords: food web, upwelling, zooplankton, trophic biomarker

Poster presentation

Physiological responses of zooplankton in the upwelling system in the Eastern South Pacific: effect of the oxygen minimum zone

Hidalgo P., Cornejo M., Ruz P. and Riquelme Bugueño R.

The intensification and expansion of the oxygen minimum zones (OMZ) may have important ecological and biogeochemical consequences affecting the population dynamic of the zooplankton species. The physiological responses to oxygen changes can be determined for the tolerance and adaptation of key zooplankton species.

Our study is to understand the physiological responses (egg and faecal pellets production, hatching success (HS) and naupliar and copepodid development rate and survival) of dominant zooplankton interacting with the OMZ of the eastern South Pacific under low oxygen concentrations. Field and experimental studies were carried during the summer and winter 2013 and summer 2014 off Mejillones, northern Chile (23°S). Dominant zooplankton species were collected: *Euphausia mucronata*, *Acartia tonsa*, *Calanus chilensis* and *Centropages brachyatus*) to several experiments on their physiological rates and oceanographic information were obtained with CTD-O (temperature, salinity, density and dissolved oxygen) and Niskin bottle (photosynthetic pigments and nutrients)

In order to determine the physiological responses of zooplankton subjected to different oxygen concentrations, adult females and naupliar and copepodid stages of copepods and early stages of *E. mucronata* were incubated in according with the specific experiment, but in two oxygen conditions at 14°C: hypoxia: $\sim 0.4 - 0.8 \text{ ml L}^{-1}$ and oxygenated ($\sim 4 - 5 \text{ ml L}^{-1}$).

Differential responses were observed for the three species under study. Our results showed that the lowest oxygen negatively affected on survival and production of eggs and pellets on *A. tonsa* and *C. brachyatus*, in contrast with the maxima egg and pellet productions on *C. chilensis* and maximum faecal pellet production on *E. mucronata*. At higher oxygen threshold the survival was higher for all species, with, however, lowest eggs and fecal pellet production in *C. chilensis* and *E. mucronata*. The Hatching success of the copepods species were negatively affected by hypoxia in contrast with oxygenated conditions, showing a decrease of 50% and 80% of hatching eggs in *C. chilensis* and *A. tonsa*, respectively. Naupliar stages were followed until stage NIII, showing that the NDR at hypoxia was slower than in oxygenated waters.

Variations on the physiological responses in zooplankton could be affected under stressful conditions due to hypoxia, determining the structure and functioning of the pelagic system. These variations could result in changes of species dominance and ecosystem productivity, influencing pelagic food web associated with the OMZs of eastern boundary upwelling systems in face of a future scenario of expansion and intensification of the OMZs.

Funding: CONICYT - N° USA 2012-0006 Project.

Keywords: Physiological responses, zooplankton, OMZ, upwelling, adaptations

Poster presentation

Meridional transport in the Benguela upwelling system and its relation to the wind forcing

Junker T., Mohrholtz V. and Schmidt M.

Winds are the largest source of momentum acting on the ocean surface layer. In the Benguela upwelling system, the wind forcing is of particular importance because the southeast trade winds drive upwelling. As a consequence, nutrients are transported into the euphotic zone and stimulate primary production. The state of the Benguela ecosystem and its productivity depends highly on the biogeochemical characteristics of the upwelling water originating typically from a depth of 100 to 200 meter. The composition of this water is largely affected by the meridional currents as the two main central water masses enter the BUS from opposite directions. The structure of the meridional currents depends on the strength and spatial shape of the wind forcing. Remotely sensed wind data that is available for a few years in high spatial resolution reveals that the wind stress exhibits spatial inhomogeneities in the order of a few 100 km that result in a wind stress curl. The present study examines the role of wind stress and wind stress curl on the meridional transport in the Benguela ecosystem by combining analytical and numerical modelling with observations. The study suggests that the meridional transport in the Benguela upwelling system may be triggered by the wind stress curl on a seasonal time scale. Inter-annual variations of the transport, however, may be explained by variations of the strength and phase of the wind stress.

Keywords: Benguela, wind stress curl, meridional currents

Poster presentation

The gelatinous component of the mesozooplankton community in the northern Benguela Upwelling System

Koppelman R., Bohata K., Jung S., Kassatov P., Kullmann B., Martin B., Möllmann C. and Reymers M.

Semi-gelatinous zooplankton organisms consisting of Thecosomata (Pteropoda), Chaetognatha and Thaliacea and gelatinous organisms consisting of Cnidaria and Ctenophora were investigated in the high-productive northern Benguela Upwelling System (BUS). The trophic positions of these animals range from herbivore and omnivore (Pteropoda and Thaliacea) to strictly carnivore (Cnidaria, Ctenophora and Chaetognatha) as confirmed by stable isotope analyses. There is some evidence that the number of large cnidarians like *Chyrsaora* spp. and *Aequorea* spp. has increased in the northern BUS since the 70th after the collapse of small-pelagic fish stocks (Clupeidae). In recent literature such increases in gelatinous organisms is referred to as jellyfication. However, little is known so far about the development of smaller Cnidaria and other gelatinous organisms in the northern BUS. In the framework of GENUS (Geochemistry and Ecology of the Namibian Upwelling System), we investigated the zooplankton community off the Namibian coast. Several transects and stations were sampled between 2008 and 2011 using a multiple closing net (MOCNESS) with 330 µm mesh aperture. The distribution and taxonomic composition of gelatinous and semi-gelatinous organisms was analyzed for different depths from onshore to offshore. Forty taxa of Cnidaria (twenty-two Medusae and eighteen Siphonophora), one taxon of Ctenophora, twenty taxa of Thecosomata, seventeen taxa of Chaetognatha and seven taxa of Thaliacea (three Doliolida and four Salpida) were found. Generally, the lowest diversity of all groups was detected on the shelf with an increasing trend towards the open ocean. The highest abundance of the carnivorous groups Coelenterata (Cnidaria and Ctenophora) and Chaetognatha was encountered at the offshore sites, but Chaetognatha were also abundant at the inner shelf station. Pteropoda were most common at the slope stations whereas Thaliacea had maximum values at the shelf break, however, this was mainly caused by a salp bloom in December 2009. Future research will focus on the long-term temporal development of the gelatinous part of the zooplankton by retrospective analyses and future monitoring, as well as on the role of these faunal components in the trophic cascade and in elemental cycling.

Keywords: Gelatinous Zooplankton, Diversity, Distribution, Benguela, Namibia

Poster presentation

The evolution of multiple stressors in the Canary upwelling system over the 21st century

Lachkar Z., Frölicher T. and Gruber N.

The Eastern Boundary Upwelling Systems (EBUS) are hotspots of rapid environmental and biogeochemical changes driven by large-scale anthropogenic perturbations such as ocean acidification, deoxygenation and climate change. Yet, the response of EBUS to these concurrent perturbations remains largely unknown and its dynamics is poorly understood. Here, we explore the potential impacts of future multiple stressors on primary production (PP), carbon cycling and the habitat size of O₂- and CO₂- sensitive species in the Canary Current System (CanCS), one of the four major EBUS. To this end, we conducted a series of transient eddy-resolving simulations of the CanCS for the 21st century (2000-2100) using the Regional Oceanic Modeling System (ROMS) coupled to a nitrogen based NPDZ biogeochemical model. The transient simulations were forced at the atmospheric and lateral boundaries with modern conditions (2000) updated with anomalies projected by the coupled carbon cycle-climate model GFDL ESM2M for the 21st century following high (RCP.8.5) and low (RCP2.6) greenhouse gas concentration trajectories.. In the course of the 21st century, the CanCS is projected to undergo increasing levels of stress, particularly elevated along the Moroccan and Iberian upwelling with intense surface warming associated with rapidly declining PP, pH and O₂ concentrations. These changes are the result of an intricate interplay between physical and biogeochemical perturbations that tend to oppose each other, thus making the prediction of the future net changes challenging. When combined, multiple stressors result in both synergistic and antagonistic effects that can not be predicted on the basis of the individual perturbations taken in isolation. We examine the projected changes in the frequency and severity of extreme low O₂, low pH events and determine when the biogeochemical conditions in the CanCS are projected to move outside of their present-day variability envelopes. The robustness of these regional projections is assessed through the quantification of the internal model variability via a series of ensemble simulations.

Keywords: Canary upwelling system, multiple stressors

Oral presentation

Organic matter cycling in the Benguela Upwelling System: Insights from amino acid biogeochemistry

Lahajnar N., Nagel B. and Emeis, K.-C.

The Benguela Upwelling System off southwestern Africa is one of the four major Eastern Boundary Upwelling Systems and is one of the most biologically productive areas in the global ocean. It is also a very particle-rich environment over the shelf. Total suspended matter is sourced by fresh biological material from nutrient and CO₂ assimilation in the shallow euphotic zone, by advection of suspended matter with upwelling intermediate water masses of the South Atlantic Ocean across the shelf break, and by sediment resuspension from diatomaceous mud deposits on the broad shelf. Organic matter sources, transport/degradation history, and reactivity during oxic and anoxic water-column remineralisation and surface sediment diagenesis are reflected in hydrolysable amino acid composition of suspended matter and surface sediments along three transects (17.3°S, 23.0°S, 28.5°S) perpendicular to the coastline. Our results clearly show that degradation state of suspended material and surface sediments is related to water depth and oxygen availability in bottom waters. A principal component analysis of the amino acid composition of suspended matter and sediments illustrates distinctly different amino acid compositions due to different sources and transport histories, and limited exchange between the two particle pools. Surface sediments contain more reactive amino acids per gram of organic carbon than suspended matter, implying that the suspended matter is imported from outside the immediate upwelling region by lateral transport. The preservation state of proteins (amino acid molar ratios in organic matter) in surface sediments within the oxygen minimum zone is better than outside. Our data also show that resuspension induced by internal waves (energy dissipation) plays a major role at the shelf break and leads to low sedimentation rates and a distinct amino acid composition of suspended matter on the outer shelf. The amount and reactivity of particulate organic matter are controlled by a complex interplay of shelf bathymetry, sediment composition, current regime and oxygen dynamics, and in turn determine the rates of remineralisation and nutrient regeneration from sediments.

Keywords: Benguela, Upwelling, amino acids, shelf biogeochemistry

Poster presentation

Physical drivers of phytoplankton production in the southern Benguela upwelling system

Lamont T. and Barlow R.G.,

Investigations of primary production (PP) were undertaken in the southern Benguela ecosystem during two research surveys in October 2006 and May 2007. Significant differences in environmental conditions, as well as biomass and PP, were observed between October and May. During October, integrated biomass and PP were significantly higher, ranging from 20.43 – 355.01 mg m⁻², and 0.71 – 6.98 gC m⁻² d⁻¹, respectively, while in May, biomass and PP were considerably lower, varying between 47.92 – 141.79 mg m⁻² and 0.70 – 3.35 gC m⁻² d⁻¹, respectively. Distribution patterns indicated low biomass and PP in newly upwelled water along the coast, higher biomass and PP in the mid-shelf region, while lower values were observed at and beyond the shelf edge. Latitudinal variations showed consistently higher biomass and PP in the St. Helena Bay region compared to biomass and PP further south off the Cape Peninsula. During both surveys, phytoplankton communities were comprised primarily of diatoms and smaller flagellates, with no significant differences between October and May. The variability in PP was thus more likely due to differences in phytoplankton physiology in response to the prevailing environmental conditions. Phytoplankton adaptation to environmental variability was characterised by increased PmB (maximum photosynthetic rate) and Ek (light saturation) under elevated temperatures and irradiance, while no clear relationships were evident for alphaB (initial slope). Irradiance was found to be the primary environmental parameter influencing vertical variations in PP, and while no definitive relationship could be established with nutrients, an optimal temperature range of 12-15°C was identified for elevated biomass and PP.

Keywords: Primary production, phytoplankton physiology, southern Benguela, Generalised Additive Models

Oral presentation

Distribution of zooplankton biomass in the northern Benguela Upwelling System

Martin B., Eggert A., Koppelman R., Diekmann R., Mohrholz V. and Schmidt M.

The distribution of zooplankton biomass in the northern Benguela Upwelling System (BUS) was studied in the framework of the project GENUS I (Geochemistry and ecology of the Namibian Upwelling System). Zooplankton were sampled with a MOCNESS (Multiple Opening and Closing Net and Environmental Sensing System, mesh-size 330 μm) during 4 expeditions in different seasons in the years 2008-2011. The biomass of the zooplankton was determined in fine-spaced depth intervals on 4 transects from onshore to offshore and compared with data obtained by a coupled hydrodynamic and ecosystem model. Remotely sensed sea surface temperatures (SSTs) as well as surface chlorophyll concentrations were analysed to investigate environmental influences. SSTs indicate that the most intense upwelling occurred from July to September in all studied years. Even though surface chlorophyll concentrations were very variable throughout the year, highest peaks were detected in September, following the maxima in upwelling of nutrient rich water. However, highest zooplankton concentrations in the upper 200 m occurred above the outer shelf and shelf-break six month after the upwelling peaks in February, while maxima were calculated for September in the simulated data. Although the temporal development differed in the two approaches, the vertical distribution of zooplankton was similar but the simulated data generally exceeded the field data in biomass with an increasing trend towards the open ocean. Despite these differences, both methods provide valuable information. The field sampling can be used for ground-truthing, taxonomic analysis and to detect variabilities and stochastic events whereas the data simulation, after further modification, can be used to smoothen variabilities and to forecast future developments in the zooplankton standing stock on the Namibian shelf under different climate change scenarios.

Keywords: Benguela, upwelling, zooplankton, field, model

Poster presentation

The remote and local physical forcing in the Northern Benguela upwelling system and its impact on the environmental conditions.

Mohrholz V., Eggert A., Junker T., Muller A.A., and Schmidt M.

The ecosystem dynamics of upwelling systems in eastern boundary currents are controlled to a large extent by the physical forcing. Namely the supply of nutrients and the oxygen conditions are affected by the upwelling dynamics. The presentation gives an overview about the patterns and variability of physical forcing in the Northern Benguela, based on field data and on the results of numerical simulations gathered during the GENUS project. In the northern Benguela, local forcing by the trade wind system and remote forcing from the tropical Atlantic determine the hydrographic conditions. The Southeast trade winds force coastal and wind stress curl driven upwelling and a quasi continuous off shore transport of surface waters. Coastal upwelling lifts cold, nutrient rich water into the euphotic zone near the coast, and forms a belt of cool water. Additionally, curl driven upwelling is forced over the shelf up to 300 km offshore due to the zonal gradient in the wind field. This type of upwelling slowly feeds nutrients into the base of the surface mixed layer, and maintains the subsurface chlorophyll maximum outside the coastal upwelling belt. The total amount of uplifted central water is in the same order of magnitude for both types of upwelling. However, the seasonal signal in the upwelling strength depicts a phase shift of 180 degree between coastal and curl driven upwelling. On a larger scale the dynamic patterns are maintained by a southward flow of oxygen depleted South Atlantic Central water (SACW) from the Angola Gyre through the Angola Benguela Frontal zone (ABFZ) and a northward transport of well oxygenated Eastern SACW (ESACW) from the Cape Basin. The Northern Benguela is the transition and mixing area of these two water masses. Their properties set the hydrographic conditions for the local environment. The front between both central water masses coincides with the change in sign of wind stress curl, indicating a system close to Sverdrup balance.

Keywords: Upwelling, Benguela, forcing, wind stress curl

Oral presentation

Benguela Upwelling System: A sink or source of CO₂ to the atmosphere?

Rixen T., Flohr A., Lahajnar N. and Gaye B.

Eastern Boundary Upwelling Systems are often associated with massive emission of CO₂ into the atmosphere due to the ascent of sub-thermocline water masses. Since these water masses are also loaded with nutrients enhancing primary production and the subsequent export of fixed CO₂ into deeper ocean it remains unclear whether upwelling systems act as CO₂ sinks or sources. As part of the international research project GENUS (Geochemistry and Ecology of the Namibian Upwelling System) we present nutrient and CO₂ data from the Benguela Upwelling System in the SE Atlantic Ocean, and demonstrate that the utilization of biologically unused phosphate (preformed PO₄) in upwelling mode-water formed at high latitudes is a key factor influencing the magnitude and regional distribution of CO₂ sinks and sources. The southern sector of the Benguela Upwelling System is a CO₂ sink caused by substantial supply and assimilation of PO₄. The northern sector is an immediate source of CO₂ acquired from mineralization of sinking organic carbon. Since the CO₂ emission in the north (14.9 Tg C yr⁻¹) exceeds the CO₂ uptake in the south (-2.9 Tg C yr⁻¹) the entire Benguela Upwelling System over the shelf is a net source of CO₂ (12 Tg C yr⁻¹).

Keywords: Benguela Upwelling, CO₂ emissions, biological pump

Oral presentation

Investigating the upwelling intensification hypothesis using climate-change simulations

Rykaczewski R.R., Dunne J. and Stock C., Sydeman W., García Reyes M., Black B. and Bograd S.

Climate variability impacts upwelling ecosystems through a number of processes including changes in upwelling-favorable winds and modification of the properties of poorly ventilated water masses supplied to the systems. One of the most ecologically significant factors is the potential for future, long-term change in the magnitude of upwelling-favorable winds in the California Current. Given the increased heating of land masses relative to oceans under increased greenhouse-gas concentrations, Bakun (1990) suggested that global warming could intensify continental thermal lows, increasing the ocean-continent atmospheric pressure gradients and the associated upwelling-favorable winds. Assessing this mechanism using observations is challenging, and relationships between winds and warming over the past decades remain equivocal. In an attempt to evaluate the upwelling intensification hypothesis comprehensively, we examined the strength and seasonality of alongshore winds in the four major upwelling systems using a suite of coupled ocean-atmosphere models assembled for the Fifth Assessment Report by the Intergovernmental Panel on Climate Change. In contrast to the hypothesized intensification, ensemble-mean model projections show relatively little change in the magnitude of winds in the upwelling areas. We suggest that the lack of a projected increased pressure gradient during summer is related to the changing relationships among temperature, pressure, and humidity. Additionally, we hypothesize that consistent changes in the seasonality and latitude of upwelling are associated with poleward migration of the major atmospheric pressure cells rather than ocean-continent temperature gradients. Such unexpected changes in upwelling winds demonstrate the potential sensitivity of upwelling to a variety of dynamic and thermodynamic processes, as well as the need to develop regionally downscaled climate models.

Keywords: upwelling intensification, anthropogenic, climate change

Oral presentation

Temperature bias in circulation models of the Benguela Upwelling Area and the implications for coupled ecosystem models

Schmidt M., Eggert A., Gerth M., Hansen A., Junker T., Mohr-Holz V, Muller A., Ohde T. and Wasmund N.

We evaluate results of coupled biogeochemical circulation models of the Benguela Upwelling System with respect to the accuracy of the simulated SST pattern and discuss implications for the ecosystem dynamics. The model is driven with different atmospheric data sets (NCEP, ECMWF) and synthetic data sets derived from satellite data. The model results are validated and compared with satellite SST data and field data and show a more or less pronounced positive SST bias. The analysis reveals two major sources of this SST bias, 1) over-estimated heat fluxes into the ocean and 2) inaccurate representation of the wind stress and wind stress curl as well. Overestimated insolation results in a large scale SST bias, which, however, is less critical for the representation of the circulation in the BUS. Unrealistic representation of the meridional wind field has consequences for strength and structure of coastal and curl driven upwelling. This can be understood from an analytical circulation model. An under-estimated wind stress curl leads to a wrong water mass distribution in the BUS similar to a permanent Benguela Nino. We discuss the consequences of enhanced SST for the ecosystem dynamics and consider shifts in the primary production, zooplankton distribution, but also in the gas surface fluxes. A special issue is the conditions for nitrogen fixation which must take place somewhere near the Benguela to compensate the nitrogen loss in sub- or anoxic waters. We demonstrate the location of optimal conditions for nitrogen fixation in dependence on the SST.

Keywords: Benguela, ecosystem model, SST, nitrogen fixation

Oral presentation

Energy demands of calanoid copepods and pelagic decapods of the Benguela Upwelling System and their contribution to active carbon flux

Schukat A., Auel H. and Hagen W.

Abundance, biomass and oxygen consumption rates of dominant calanoid copepods and pelagic decapods at two sampling sites (Kunene line, ~17°S and Walvis Bay line, 23°S) in the northern Benguela upwelling system were investigated to determine their energy requirements and assess their significance in the carbon cycle of the Benguela Current. Copepods were sampled with a 0.25 m² multiple opening and closing net (Multinet midi), while a larger net (1 m² MOCNESS) was used for the collection of decapods. Copepods (4 - 32 x 10³ ind. m⁻²) had a much higher abundance as compared to decapods (<1 - 19 ind. m⁻²). However, their biomass was in the same order of magnitude. Biomass of copepods and decapods was highest at the northern transect (~17°S) with values of 1776 mg C m⁻² and 548 mg C m⁻², respectively. At the southern transect (23°S) biomass maxima reached 442 mg C m⁻² for copepods and 292 mg C m⁻² for decapods. An energy budget approach was performed to calculate carbon ingestion rates. Total carbon consumption of both taxa was 146 mg C m⁻² d⁻¹ at the Kunene line and 85 mg C m⁻² d⁻¹ at the Walvis Bay line with copepods contributing the major portion of >80% to total consumption. The active carbon flux out of the euphotic zone due to vertically migrating species was estimated with 8 mg C m⁻² d⁻¹ off Kunene and 12 mg C m⁻² d⁻¹ off Walvis Bay, which is equivalent to 47% and 70% of sinking POC, respectively. Thus, both copepods and decapods seem to play an important role in the biological carbon pump of the Benguela upwelling system, especially in the region off Walvis Bay. The presented data set is essential for the development of realistic carbon budgets and food-web models for the Benguela Current.

Keywords: Respiration, Carbon consumption, migration, carbon flux

Poster presentation

Water mass analysis of the Benguela upwelling system referring to the oxygen minimum zone

Tim N., Zorita E. and Hünicke B.

The Namibian upwelling region is one of the four Eastern Boundary Upwelling Ecosystems and among the most productive areas in the World Ocean. One important question is how the upwelling dynamics have varied in the past and will change in the future. The identification of the influence of the large-scale climate patterns on the Namibian EBU can shed light on this question. With this goal in mind we have analysed the large-scale atmospheric influence on the upwelling system with high-resolution simulations with the global ocean models MPI-OM (covering the last 50 years and driven by the global atmospheric reanalysis NCEP) and with the regional MOM4 model (covering the last 15 years). The subtropical anticyclone, the southeasterly trades and ENSO have been detected as the main large-scale modulators of the upwelling intensity. The spatial and temporal differences of the atmospheric drivers between simulations and between simulations and observations have been identified.

The oxygen minimum zone (OMZ) in the Benguela region has an important impact on the ecosystem and local fisheries. The content of South Atlantic Central Water (SACW) on the shelf drives the intensity and extension of the oxygen minimum zone. The SACW is transported by the poleward undercurrent from the Angola Dome to the Benguela region. The oxygen-rich Eastern South Atlantic Central Water (ESACW) is transported northward with the Benguela Current. Therefore, the analysis of the water masses, their origin and pathways through the South Atlantic as well as trends and variabilities of the OMZ is being analysed with the high resolution ocean model simulation (MOM) and the MPI-ESM runs of the Climate Model Intercomparison project 5 covering the historical period 1850-present. Although the resolution of the latter simulation may be too coarse, this climate model includes a biogeochemistry submodel HAMOCC which facilitates the analysis of the dynamics of the OMZ. Preliminary results will be presented at the conference.

Keywords: Benguela, Upwelling, OMZ, SACW

Poster presentation

Recent climatic trends modulate ongoing ocean acidification in the California Current System

Turi G., Lachkar Z., Münnich M., Gruber N., Loher D

Rising atmospheric CO₂ concentrations are driving widespread ocean acidification, thus challenging coastal upwelling ecosystems with naturally low pH conditions such as the California Current System (CalCS). The magnitude of this coastal acidification is also sensitive to concurrent physical perturbations driven by climate change such as upper ocean warming and altered upwelling-favorable winds. Here, we investigate the recent progression of ocean acidification in the CalCS over the last three decades (1979-2012) and tease out its individual drivers.

Using an eddy-resolving physical-biogeochemical model of the CalCS on the basis of the Regional Oceanic Modeling System (ROMS), we ran a hindcast simulation with increasing CO₂ conditions and varying physical atmospheric forcing, to investigate changes in the carbonate chemistry from 1979 to 2012. Our initial analyses indeed show a significant increase in surface ocean pCO₂ and concurrent significant decreases in pH and Omega aragonite, which can be directly linked to the rise in atmospheric CO₂ over this time period. These CalCS-wide trends are however modified regionally, in response to additional changes in the climatic forcing: Firstly, due to changes in wind-driven upwelling, trends in pCO₂, pH and Omega aragonite are substantially enhanced in the nearshore 100 km between Point Arena, California and Cape Blanco, Oregon (~39-43°N), where pCO₂ has increased by about +70 ppm and pH and Omega aragonite have dropped by about -0.07 and -0.28, respectively. Secondly, roughly between 100-800 km offshore, the overlying trends in pCO₂ and pH are slightly dampened due to a decrease in sea surface temperatures and a rise in net primary production. This results in smaller, but nevertheless significant changes in pCO₂ and pH of +50 ppm and -0.05, respectively, whereas Omega aragonite has decreased by roughly the same amount as in the nearshore 100 km.

The individual contributions of increasing CO₂ conditions and changing surface temperature and alongshore winds are assessed through a series of sensitivity simulations where either the CO₂ conditions or the physical forcing are kept constant at the 1979 value. The importance of remote versus local forcing is further quantified for each individual driver by contrasting simulations forced with fully-transient versus climatological lateral boundary conditions.

Keywords: Ocean acidification, California Current System, ROMS

Oral presentation

Contribution of mesozooplankton to the vertical flux of organic carbon in the northern Benguela Upwelling System off Namibia

Werner T., Schukat A., Martin B. and Buchholz F.

The prevailing vertical transport of carbon produced by phytoplankton in the upper water layers of the ocean to deeper zones takes place by sinking of particulate organic carbon (POC). Several processes mediated by the zooplankton community can either enhance or limit the vertical carbon flux and regulate the efficiency of the biological carbon pump. Main biological pathways by which carbon is exported to deeper water layers are the active transport of carbon by vertical migration of pelagic animals and the passive transport of faecal pellets. Vertically migrating zooplankton may in this way significantly contribute to the dissolved inorganic carbon (DIC) pool by respiration and the dissolved organic carbon (DOC) pool by excretion. In the northern Benguela Upwelling System (BUS) jellyfish, krill, copepods, decapods and occasionally salps dominate the mesozooplankton community in terms of biomass.

We will present a conceptual model, combining diel vertical migration (DVM) patterns of dominant krill species, with environmental parameters such as temperature, food availability and with physiological constraints such as species-specific respiration rates that may explain seasonal adaptations of DVM to changes in water temperature, oxygen and food availability. Additionally, we will show how the different taxa contribute to the downward transport of organic carbon by vertical migration (Krill, copepods and decapods) or through high amounts of fast sinking faeces (salps). Variable spatial and temporal distributions, such as a high patchiness of krill, decapods and salps and a more homogenous horizontal distribution of copepods will lead to seasonal and regional differences in the export of organic carbon. Furthermore, high primary production in the upper water layers related to upwelling intensity enhances the carbon export due to phytoplankton sinking after a bloom and/or faecal pellet production and grazing by zooplankton. Overall, we will estimate the role of zooplankton in the downward transport of carbon and assess its importance relative to other vertical carbon fluxes in the BUS.

Keywords: biological carbon pump, zooplankton, Benguela Current

Oral presentation

Session G2: IMBER National Programme Contributions

An overview of IMBER activities in France

Carlotti F. et al.

France CYBER/Bio-Argo DATABASE service

Claustre H. et al., Presented by Carlotti F.

Data management in support of IMBER research

Chandler C. et al.

IMBER related activities in Ireland

Croot P. et al.

IMBER-related activities of the Greek scientific community

Gogou A. et al.

Food-web modelling of New Zealand coastal and offshore systems in support of an ecosystem approach to marine management

Pinkerton M. and Hall J.

Biogeochemical and Ecosystem Research in the Seas surrounding Taiwan - Highlights on IMBER-related Research in Taiwan

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UK IMBER related science activities

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IMBER related activities in Turkey

Salihoglu B. et al.

Overview about the IMBER-related research activities in Italy

Solidoro C.

An overview of IMBER activities in France

Carlotti F., Obernosterer I., Aumont O., Boyé M., Cardinal D., Cossa D., d'Ortenzio F. and Garçon V.

IMBER national activities in France are developed through National, European and International funded programs. At the national level, several programmes (CYBER, MERMEX, TOSCA, ...) contribute to fund research activities aiming to investigate the sensitivity of marine biogeochemical cycles and ecosystems to global change, on time scales ranging from years to decades. This poster aims to give an overview of the recently achieved projects and of the objectives of on-going projects.

Keywords: IMBER France projects facilities database

Poster presentation (ID: G2.P1)

France CYBER/Bio-Argo DATABASE service

Claustre H. and Schmechtig C. Presented by Carlotti F.

Formally launched during the JGOFS era, the main objectives of the now called LEFE/CYBER database service are to make an inventory of all the physical and biogeochemical data collected during open ocean operations in the framework of LEFE/CYBER projects. Data are subsequently archived and made available to the whole scientific community. More recently, the new types of measurements acquired by Bio-Argo profiling floats are also managed by the service.

Keywords: Database physical biogeochemical open-ocean campaigns

Poster presentation (ID: G2.P2)

Data management in support of IMBER research

Chandler C., Groman T.V., Allison M.D., Wiebe P.H., , P.H.Shepherd, A., Kinkade, D., Rauch, S., Gegg, S.R., Copley N. and Glover D.M.

Good data management practices are part of the necessary infrastructure that supports successful scientific research. The types of research projects endorsed by the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project involve multi-disciplinary topics and are therefore likely to require integration of data from disparate sources. Such integration can only be done if one can first discover the needed resources, assess 'fitness-for-purpose' and then have access to sufficient metadata (supporting documentation) to enable accurate interpretation of heterogeneous data and re-use of those data beyond the expectations of the original investigators.

Using a US-funded IMBER project as a case study, this presentation describes the essential data management activities that should be addressed by every researcher to facilitate access to resultant data by research colleagues and others. The components include: (1) working with data management professionals to establish a comprehensive data management plan; (2) registering the IMBER-endorsed project at the Global Change Master Directory (GCMD; gcmd.nasa.gov/) portal; (3) ensuring reliable backup of data and supporting documentation; (4) contributing data to a system that supports data discovery, access, display, assessment, integration, and export of the data; (5) submitting final data sets to the appropriate long-term data archive and (6) formal publication of data sets to provide citable references (Digital Object Identifiers) for publishers of the peer-reviewed literature and to encourage proper citation and attribution of data sets in the future. When combined, these elements comprise the full spectrum of the data life cycle; enabling discovery and accurate re-use and ensuring long-term permanent archive of the data that are an important component of a researcher's legacy.

Related URL: <http://bco-dmo.org>

Keywords: data management, marine ecosystem, ocean biogeochemistry

Poster presentation (ID: G2.P3)

IMBER related activities in Ireland

Croot P., Cave R., Fennell S., McGovern E., McGrath T., Raine, R., Ward, B., White M. and Wilson A.

IMBER related activities in Ireland are rapidly gathering momentum as existing research efforts are blended with new lines of research. Presently IMBER related research in Ireland is focused on several inter-related themes;

- Air-Sea Exchange
- Ocean Acidification
- Ocean Deoxygenation
- Carbon system dynamics around Ireland
- Estuarine nutrient cycling
- Biogeochemical cycling along the west coast of Ireland
- Benthic-pelagic coupling along the Irish continental shelf,
- Transport of matter in nepheloid layers in submarine canyons,
- Role of mesoscale eddies in forming deep scattering layers in the North Atlantic
- Impacts of Climate Change on HABs

This work is performed over a wide range of estuarine, coastal and open ocean environments within the Irish EEZ and the wider North Atlantic using the Marine Institute's vessels, the Celtic Voyager and Celtic Explorer, and in collaboration with international partners. Irish scientists are keen to develop further collaborations with international colleagues in all aspects of IMBER research, most notably with respect to establishing long term observatories in the Atlantic.

Keywords: IMBER Ireland Biogeochemistry Climate Change

Poster presentation (ID: G2.P4)

IMBER-related activities of the Greek scientific community

Gogou A. and Frangoulis C.

We hereby summarize the IMBER-related activities of the Greek scientific community. Biogeochemical studies of this community aim the impacts of atmospheric deposition of particles like Saharan dust and polluted aerosols to ecosystem functioning of the Eastern Mediterranean Sea (EMS), understanding the variability of biogeochemical fluxes (e.g. in the deepest Mediterranean observatory), vulnerability of pelagic and deep-sea ecosystems to regional and global stressors, going from coastal anthropogenic impact of multiple stressors to oligotrophic open ocean sensitivity to global change. Such studies have indicated several phenomena that show interactions between global change, anthropogenic stressors, biogeochemical cycles and marine food webs. Links of changes in the thermohaline circulation (e.g. the Eastern Mediterranean Transient) to productivity and biogeochemical fluxes to depth, wind-generated coastal upwellings to productivity of ecosystems, atmospheric deposition of nutrients as drivers of productivity episodes, impact of progressive combined warming and acidification as threats of vulnerable ecosystems etc. These studies are based on sustained monitoring of particular hot spot areas and the combination of multiple tools.

Geographically speaking projects are sustained in hot spots areas like in the proximity of the Straits between Black Sea and Mediterranean Sea, the Ionian Sea including the deepest areas in the Mediterranean Sea, oligotrophic areas away from local anthropogenic impact (Cretan Sea and NE Levantine) and areas with strong human activities (Athens, Thessaloniki). Projects progressively expand geographically beyond the Seas surrounding Greece, by Greek participation-coordination in large regional projects (in the Mediterranean and Black Sea) and sustained collaboration with research institutes in the Red Sea.

Tools include deep-ocean observatories, operational oceanography platforms progressively upgraded with biochemical sensors, repeated biochemical sampling by R/V, biogeochemical-ecosystem modelling with a more Ecosystem End to End approach, experiments of the impact of multiple (including combined) stressors in the laboratory or in the unique land-based mesocosm facilities in the Eastern Mediterranean. National data management is done by a national database (HNODC) in close collaboration with European and international databases. HNODC is progressively increasing the number of biochemical parameters handled by the database. In order to reply to the demand of policy and societal needs not only from Greece but also from European countries, and countries surrounding the Mediterranean and Black Sea, there is an increased scientific effort to assess the relationships between marine biogeochemical cycles and ecosystems with human societies. The assessment examines the effect of natural and human-made combined pressures in socio-economic terms, in order to promote better governance for implementation of adaptive policies and management schemes.

All the above efforts are based on stable collaborations among different national research institutions as well as with institutions abroad Greece. We finally summarize future plans concerning biogeochemical and ecosystem studies through the development of a long term monitoring strategy and of tools for studying the biogeochemical particularities of the EMS.

Keywords: Greece, Eastern Mediterranean, IMBER-related activities
Poster presentation (ID: G2.P5)

Food-web modelling of New Zealand coastal and offshore systems in support of an ecosystem approach to marine management

Pinkerton M. and [Hall J.](#)

Research to understand the structure and function of two key regions of New Zealand forms part of an IMBER-endorsed project.

Offshore: The Chatham Rise is a submarine ridge east of New Zealand which lies within the circumpolar Subtropical Convergence Zone. Elevated primary production in the Chatham Rise region supports high abundances of mesopelagic fish and pelagic, benthic and hyperbenthic invertebrates. These “middle trophic level” groups form the basis of the diet of important commercially-harvested fishes, including hoki (*Macruronus novaezelandiae*), New Zealand’s largest fishery. We report on analysis of data from two Fisheries Oceanography voyages to the Chatham Rise, which focussed on quantifying the abundance, distribution and trophic connections of key middle-trophic level taxa. A trophic model of the region has been developed and is presented.

Coastal: Foodweb modelling was used to explore how the structure and functioning of the Hauraki Gulf ecosystem has changed during human occupation. We developed 5 food-web models: (1) present day; (2) 1950 AD, just prior to onset of industrial-scale fishing; (3) 1790 AD, before European whaling and sealing; (4) 1500 AD, early Maori settlement phase; (5) 1000 AD, before human settlement in New Zealand. The models had groups representing biota from bacteria to whales. Biomass and catch parameters were derived from information including historical reconstructions of catch histories, fisheries stock modelling, historical evidence, archaeological information (middens), reconstructions of past climate, or evidence gleaned from narratives. A semi-objective balancing method was used to adjust simultaneously all parameters, minimizing changes in parameters while taking into account relative uncertainties. Trophic levels in the present day model agreed well with stable isotope data taken in the study area. The historical ecosystem models reveal substantial changes in the pattern of ecological importance during human occupation. In the models, marine mammals, sharks and crayfish have declined in ecological importance, while birds, smaller fish (large reef fish, kahawai, snapper), and crabs have increased in ecological importance.

Keywords: Food-web modelling, ecosystem approach

Poster presentation (ID: G2.P10)

Biogeochemical and Ecosystem Research in the Seas surrounding Taiwan - Highlights on IMBER-related Research in Taiwan

Liu K.K. and Gong G.C.

Quite a few important Taiwanese research projects are closely related to IMBER, though nominally Taiwan has no dedicated IMBER projects. One prominent integrated project, entitled “Effects of Global Change on Ocean Biogeochemistry and Ecosystems in the Seas surrounding Taiwan in the Northwest Pacific” (ECOBEST) was launched in 2011. ECOBEST is the extension of the project, Long-term Observation and Research of the East China Sea (LORECS) project. In the previous phase, one of the most important findings was the flood-induced phytoplankton bloom in the Changjiang (aka the Yangtze River) outflow region in the East China Sea shelf in summer (Gong et al., 2011, GRL). Intense phytoplankton growth was associated with strong CO₂ drawdown resulting in strengthened CO₂ sink (Tseng et al., 2011, GRL). Typhoons enhanced phytoplankton growth in the East China Sea, which led to elevated export production (Hung et al., 2010, BG).

The on-going ECOBEST project consists of 20 sub-projects with topics ranging from ocean circulation in the western North Pacific Ocean to biogeochemistry of Aeolian fluxes of iron, from primary production to microbial food loop and coral reef ecology. The emphases are on how external forcing (such as dust deposition, river discharges, monsoons and typhoons) and physical processes (such as boundary currents, tides and internal waves) control biogeochemistry and marine ecosystem. Special foci are given to effects of acidification on coral reefs and impacts of human-induced environmental change (such as hypoxia) on fisheries resources. The major approach still employs the traditional shipboard observations, but research methodology also covers remote sensing, atmospheric modeling of Aeolian transport and ocean modeling of currents, nutrient transport and lower trophic levels of marine ecosystems.

There are also research projects focused on the South China Sea. The South-East Asia Time-series Study (SEATS) project has been conducted since 1998 and is now carried out mainly by the Research Center for Environmental Changes, Academia Sinica after a few years' hiatus. The main purpose of the SEATS is to better understand the biogeochemical processes under different physical forcings in time scales ranging from short-term events (e.g., typhoons) to seasonal changes (e.g., monsoons) and inter-annual oscillations (e.g., ENSO). It has been demonstrated that the biogeochemical responses of the South China Sea to climate oscillation are quite pronounced but different from those in other parts of the tropical Pacific Ocean (Liu et al., 2013, BG), that may lead to unique climate records stored in the sediments.

Keywords: East China Sea, South China Sea

Poster presentation (ID: G2.P12)

The biogeochemistry from the oligotrophic to the ultraoligotrophic Mediterranean (BOUM) experiment

Moutin T.

The modifications of the biological pump following climate change will probably largely influence the oceanic carbon sequestration (and therefore global warming) over a decadal time scale. Prediction in the 21st century seems to indicate an oligotrophication of the ocean, resulting in a weakening of the transfer of carbon to the ocean interior and a concomitant acceleration of climate change. In order to determine the present state and forecast the future efficiency of the biological pump, major challenges concern biogeochemical, physical and biological oceanography.

The BOUM (Biogeochemistry from the Oligotrophic to the Ultraoligotrophic Mediterranean) experiment, endorsed by the IMBER program has one overall goal: to obtain a better representation of the interactions between planktonic organisms and the cycle of biogenic elements, considering scales from single process to the whole Mediterranean Sea (MS). It was organized on three main objectives, 1: to give a longitudinal description of the biogeochemistry and biological diversity of the MS during the strongest stratified period, 2: to study in 3 oligotrophic environments located at the center of anticyclonic eddies, the production and fate of organic matter with particular emphasis on the processes which drive the divergence of the stoichiometric ratios of the biogenic elements in the organic matter found in the surrounding water and exported materials, and 3: to obtain a satisfactory representation of the main biogeochemical fluxes (C, N, P, Si) and the dynamics of the planktonic trophic network, both in situ and by using microcosm experiments.

The data set is available on several data bases following the links given in our web site: <http://mio.pytheas.univ-amu.fr/BOUM/?lang=en>.

The numerous results were published in 25 papers in a Biogeosciences special issue entitled "Interactions between planktonic organisms and the biogeochemical cycles of biogenic elements in the Mediterranean Sea during intense summer stratification: the BOUM experiment" in 2011 (http://www.biogeosciences.net/special_issue82.html), and 8 other papers in different journals. We particularly confirmed the strong depletion in P vs N, even higher in the eastern part of the MS which confirmed the LPLC (Low-P Low-Chlorophyll) characteristics of the oligotrophic MS. We have shown that the mesoscale activity is strong enough to delete (or even reverse) the very well-known western to eastern gradient of trophic conditions in the MS, and also the importance of this mesoscale activity on vertical exchanges of water properties and biogeochemical budgets. A surprisingly quasi Redfieldian $\Delta(\text{NO}_3):\Delta(\text{PO}_4)$ compartment of deep waters throughout the eastern and western MS was found.

Keywords: Biogeochemistry, biological pump, nutrient cycles, Mediterranean

Poster presentation (ID: G2.P6)

UK IMBER related science activities

Murphy E.J., Robinson C., Cavanagh R. and Johnston N.

Will note major UK activities in related to IMBER science, including programmes in Southern Ocean ecosystems (ICED), the Atlantic Meridinnal Transect, ocean acidification, shelf seas biogeochemistry, ecosystem modelling and other more specific biogeochemistry and ecosystem science activities.

Keywords: biogeochemistry, ecosystems

Poster presentation (ID: G2.P7)

IMBER related activities in the western South Atlantic

Piola A.P., Bianchi A., Lutz V.A., Marrari M., Negri R., Palastanga V., Sabatini M., and Viñas M.D.

Poster about the IMBER-related activities in the western South Atlantic

Keywords: IMBER-related activities; western South Atlantic

Poster presentation (ID: G2.P8)

IMBER related activities in Turkey

Salihoglu B. and Oguz T.

Main IMBER related activities in Turkey focuses on the Mediterranean, Marmara and the Black Seas. In this poster we will present the activities that focuses on the impact of environmental and climatic stressors on the marine biogeochemical cycles and ecosystems. Despite limited observational programmes, several institutes located at the Mediterranean and Black Sea coasts carry out regional surveys, which provide valuable input assessing Turkish seas. IMBER related research activities are mostly supported by small scale national funding or through EU projects. These efforts are recently supported by the Marine Ecosystem and Climate Center (DEKOSİM), established at Institute of Marine Sciences Campus of Middle East Technical University located in Turkey/Eastern Mediterranean IMS METU. DEKOSİM is an interdisciplinary centre of excellence funded by Turkish Ministry of Development. The main objective is to create an infrastructure that focuses on interdisciplinary research that would link marine physical, chemical, biological and geological research. Most academic members of IMS-METU and several other researchers from other national institutions have contributed to the establishment. With over 35 years experience in marine research by these institutes in the Mediterranean and Black Sea, DEKOSIM aims to become a marine research centre serving all national and international researchers in the marine ecosystem and climate fields. Although modelling is carried out by a small group of scientists in Turkey end-to-end models with predictive capacity are developed for the Black Sea region. An effort to increase the capacity in the field of modelling is underway for the Mediterranean and Marmara Seas.

Keywords: IMBER, Turkey

Poster presentation (ID: G2.P9)

Overview about the IMBER-related research activities in Italy

Solidoro C.

The poster gives an overview about the recent IMBER-related research activities in Italy.

Keywords: Italy, IMBER

Poster presentation (ID: G2.P11)

List of Participants

Agusti, Susana

Mediterranean Institute for Advanced
Studies, CSIC
Australia
sagusti@imedea.uib-csic.es

Akhand, Anirban

Jadavpur University
India
anirban.akhand@gmail.com

Aksnes, Dag

University of Bergen
Norway
dag.aksnes@bio.uib.no

Alabia, Irene

Hokkaido University
Japan
irenealabia@gmail.com

Alcaraz, Miquel

Institut de Ciències del Mar, CSIC
Spain
miquel@icm.csic.es

Allison, Edward

University of Washington
USA
eha1@uw.edu

Anderson, Thomas

National Oceanography Centre,
Southampton
UK
tra@noc.ac.uk

Arandia Gorostidi, Nestor

Instituto Español de Oceanografía
Spain
nestor.arandia@gi.ieo.es

Ardelan, Murat

Norwegian University of Science and
Technology
Norway
murat.v.ardelan@ntnu.no

Arístegui, Javier

Universidad de Las Palmas de Gran Canaria
Spain
javier.aristegui@ulpgc.es

Arrizabalaga, Haritz

AZTI-Tecnalia
Spain
harri@azti.es

Artioli, Yuri

Plymouth Marine Laboratory
UK
yuti@pml.ac.uk

Asch, Rebecca

Princeton University
USA
rasch@princeton.edu

Assmy, Philipp

Norwegian Polar Institute
Norway
philipp.assmy@npolar.no

Auel, Holger

University of Bremen
Germany
hauel@uni-bremen.de

Austin, Peter

University of Plymouth
UK
peter.austin@postgrad.plymouth.ac.uk

List of Participants

Avril, Bernard

IMBER International Project Office, IMR
Norway
avrilb@imr.no

Ayata, Sakina-Dorothee

Observatoire Océanologique de
Villefranche-sur-Mer, CNRS-UPMC
France
sakina@obs-vlfr.fr

Azam, Farooq

Scripps Institution of Oceanography
USA
fazam@ucsd.edu

Bach, Lennart

GEOMAR
Germany
lbach@geomar.de

Bailey, Jennifer

Norwegian University of Science and
Technology
Norway
jennifer.bailey@svt.ntnu.no

Bakker, Dorothee

University of East Anglia
UK
d.bakker@uea.ac.uk

Balino, Beatriz

University of Bergen
Norway
beatriz.balino@skd.uib.no

Bandounas, Luaine

Elsevier B.V.
The Netherlands
l.bandounas@elsevier.com

Battaglia, Gianna

University of Bern
Switzerland
battaglia@climate.unibe.ch

Beckley, Lynnath

Murdoch University
Australia
l.beckley@murdoch.edu.au

Bedford, Merel

University of Tasmania
Australia
mbedford@postoffice.utas.edu.au

Belcher, Anna

National Oceanography Centre,
Southampton
UK
a.belcher@noc.soton.ac.uk

Bellerby, Richard

Norwegian Institute for Water Research
Norway
richard.bellerby@niva.no

Berger, Stella

Leibniz Institute of Freshwater Ecology and
Inland Fisheries
Germany
berger@igb-berlin.de

Berman-Frank, Ilana

Bar Ilan University
Israel
ilana.berman-frank@biu.ac.il

Bianchi, Alejandro

Servicio de Hidrografia Naval
Argentina
abianchi@hidro.gov.ar

Bianchi, Daniele

McGill University
Canada
daniele.bianchi@mail.mcgill.ca

Blain, Stéphane

Observatoire Océanologique de
Banyuls-sur-mer, CNRS-UPMC
France
stephane.blain@obs-banyuls.fr

List of Participants

Blasiak, Robert

University of Tokyo
Japan
a-rb@mail.ecc.u-tokyo.ac.jp

Blenckner, Thorsten

Stockholm Resilience Centre
Sweden
thorsten.blenckner@stockholmresilience.s
u.se

Boatman, Toby

University of Essex
UK
tboatm@essex.ac.uk

Bohata, Karolina

Hamburg University
Germany
karolina.bohata@uni-hamburg.de

Bopp, Laurent

Laboratoire des Sciences du Climat et de
l'Environnement, IPSL
France
laurent.bopp@lscce.ipsl.fr

Borja, Angel

AZTI-Tecnalia
Spain
aborja@azti.es

Botsford, Louis

University of California, Davis
USA
lwbotsford@ucdavis.edu

Bouquet, Jean-Marie

University of Bergen
Norway
jean-marie.bouquet@sars.uib.no

Bouvet, Antoine

Laboratoire d'Océanographie et du Climat,
CNRS-UPMC
France
anblod@locean-ipsl.upmc.fr

Boyce, Daniel

Bedford Institute of Oceanography
Canada
dboyce@dal.ca

Bratkic, Arne

Institute Jožef Stefan
Slovenia
arne.bratkic@ijs.si

Broadgate, Wendy

International Geosphere-Biosphere
Programme (IGBP)
Sweden
wendy@igbp.kva.se

Brust-Möbius, Juliane

Leibniz Institute for Baltic Sea Research
Germany
juliane.brust@io-warnemuende.de

Buchholz, Friedrich

Alfred Wegener Institute for Polar and
Marine Research
Germany
friedrich.buchholz@awi.de

Bundy, Alida

Bedford Institute of Oceanography
Canada
alida.bundy@dfo-mpo.gc.ca

Buttay, Lucie

Instituto Español de Oceanografía
Spain
lucie.buttay@gi.ieo.es

Cabre, Anna

University of Pennsylvania
USA
annanusca@gmail.com

Calbet, Albert

Institut de Ciències del Mar, CSIC
Spain
acalbet@icm.csic.es

List of Participants

Campagna, Claudio

Wildlife Conservation Society
Argentina
ccampagna@wcs.org

Carlotti, Francois

Mediterranean Institute of Oceanography
France
francois.carlotti@univ-amu.fr

Castano Primo, Rocio

University of Bergen
Norway
rocio.primo@gfi.uib.no

Cavan, Emma

National Oceanography Centre,
Southampton
UK
e.cavan@noc.soton.ac.uk

Cavanagh, Rachel

British Antarctic Survey
UK
rcav@bas.ac.uk

Certain, Gregoire

Norwegian Institute for Nature Research
Norway
gregoire.certain@nina.no

Chaalali, Aurélie

Université de Caen Basse-Normandie
France
aurelie.chaalali@unicaen.fr

Chakraborty, Kunal

INCOIS
India
kunal.c@incois.gov.in

Chandler, Cynthia

Woods Hole Oceanographic Institution
USA
cchandler@whoi.edu

Chen, Jianfang

Second Institute of Oceanography, SOA
China
jfchen@sio.org.cn

Cheung, William

University of British Columbia
Canada
w.cheung@fisheries.ubc.ca

Chiba, Sanae

JAMSTEC
Japan
chibas@jamstec.go.jp

Christensen, Villy

University of British Columbia
Canada
v.christensen@fisheries.ubc.ca

Chuenpagdee, Ratana

Memorial University
Canada
ratanac@mun.ca

Clement, Dominic

ETH Zurich
Switzerland
dominic.clement@env.ethz.ch

Cochrane, Sabine

Akvaplan-niva
Norway
skc@akvaplan.niva.no

Coll, Marta

Institute for Research and Development
France
marta.coll@ird.fr

Conchon, Anna

Collecte Localisation Satellites (CLS)
France
aconchon@cls.fr

List of Participants

Constable, Andrew

Australian Antarctic Division
Australia
andrew.constable@aad.gov.au

Conversi, Alessandra

Istituto di Scienze Marine, CNR
Italy
a.conversi@ismar.cnr.it

Coppola, Laurent

Observatoire Océanologique de
Villefranche-sur-Mer, CNRS-UPMC
France
coppola@obs-vlfr.fr

Corney, Stuart

Antarctic Climate and Ecosystems
Cooperative Research Centre
Australia
stuart.corney@acecrc.org.au

Costa, Daniel

University of California, Santa Cruz
USA
costa@ucsc.edu

Criddle, Keith

University of Alaska, Fairbanks
USA
kcriddle@alaska.edu

Croot, Peter

National University of Ireland, Galway
Ireland
peter.croot@nuigalway.ie

Cross, Jessica

University of Alaska, Fairbanks
USA
jncross@alaska.edu

Cuevas, Luis Antonio

University of Concepción
Chile
lcuevas@udec.cl

Currie, Kim

NIWA
New Zealand
kim.currie@niwa.co.nz

D'Adamo, Nick

IOC, Perth
Australia
nick.dadamo@bom.gov.au

Dadou, Isabelle

Laboratoire d'Etudes en Géophysique et
Océanographie Spatiales
France
isabelle.dadou@legos.obs-mip.fr

Daewel, Ute

Nansen Environmental and Remote
Sensing Centre
Norway
ute.daewel@nersc.no

Dang, Hongyue

Xiamen University
China
danghy@xmu.edu.cn

Darnis, Gerald

Akvaplan-niva
Norway
gerald.darnis@akvaplan.niva.no

Dautovic, Jelena

Rudjer Boskovic Institute
Croatia
jdautov@irb.hr

David, Niv

University of Haifa
Israel
nivdd@yahoo.com

de Boissieu, Florian

Laboratoire d'Océanographie et du Climat,
CNRS-UPMC
New Caledonia
fdeboiss@gmail.com

List of Participants

De Kok, Jean-Luc

Flemish Institute for Technological
Research
Belgium
jeanluc.dekok@vito.be

Degen, Renate

Alfred Wegener Institute for Polar and
Marine Research
Germany
renate.degen@awi.de

Drinkwater, Ken

Institute of Marine Research
Norway
ken.drinkwater@imr.no

Du, Chuanjun

Xiamen University
China
cjdu@stu.xmu.edu.cn

Dueri, Sibylle

Institute for Research and Development
France
sibylle_dueri@hotmail.com

Dunton, Kenneth

Marine Science Institute, Texas University
USA
ken.dunton@utexas.edu

Duteil, Olaf

GEOMAR
Germany
oduteil@geomar.de

Eddy, Tyler

Dalhousie University
Canada
tyler.eddy@dal.ca

Edwards, Martin

Sir Alister Hardy Foundation for Ocean
Science
UK
sahfos@sahfos.ac.uk

Egge, Jorun Karin

University of Bergen
Norway
jorun.egge@bio.uib.no

Eggert, Anja

Leibniz Institute for Baltic Sea Research
Germany
anja.eggert@io-warnemuende.de

Eide, Marie

University of Bergen
Norway
marie.eide@gfi.uib.no

Ejsmond, Maciej

University Centre in Svalbard
Norway
maciej.ejsmond@unis.no

Ekau, Werner

Leibniz Center for Tropical Marine Ecology
Germany
wekau@zmt-bremen.de

Elliott, Mike

University of Hull
UK
mike.elliott@hull.ac.uk

Emeis, Kay-Christian

Helmholtz Centre for Environmental
Research
Germany
kay.emeis@zmaw.de

Endres, Sonja

GEOMAR
Germany
sendres@geomar.de

Escribano, Ruben

Universidad de Concepcion
Chile
rescribano@udec.cl

List of Participants

Färber-Lorda, Jaime

CICESE
Mexico
jfarber@cicese.mx

Fassbender, Andrea

University of Washington
USA
afassben@uw.edu

Feely, Richard

Pacific Marine Environmental Laboratory,
NOAA
USA
richard.a.feely@noaa.gov

Fennel, Wolfgang

Leibniz Institute for Baltic Sea Research
Germany
wolfgang.fennel@io-warnemuende.de

Fernandez Chacon, Albert

Institute of Marine Research
Norway
albert.chacon@imr.no

Fiechter, Jerome

University of California, Santa Cruz
USA
fiechter@ucsc.edu

Fiksen, Øyvind

University of Bergen
Norway
oyvind.fiksen@bio.uib.no

Flecha, Susana

Instituto de Ciencias Marinas de Andalucía,
CSIC
Spain
susana.flecha@icman.csic.es

Flohr, Anita

Leibniz Center for Tropical Marine Ecology
Germany
anita.flohr@zmt-bremen.de

Fox, Peter

Rensselaer Polytechnic Institute
USA
pfox@cs.rpi.edu

Francois, Roger

University of British Columbia
Canada
rfrancois@eos.ubc.ca

Frischer, Marc

Skidaway Institute of Oceanography
USA
marc.frischer@skio.uga.edu

Frøb, Friederike

University of Bergen
Norway
friederike.frob@gfi.uib.no

Fujiwara, Amane

National Institute of Polar Research
Japan
fujiwara.amane@nipr.ac.jp

Fulton, Beth

CSIRO
Australia
beth.fulton@csiro.au

Furevik, Tore

University of Bergen
Norway
tore@gfi.uib.no

Galbraith, Eric

McGill University
Canada
eric.galbraith@mcgill.ca

Gao, Shuang

University of Bergen
Norway
shuang.gao@gfi.uib.no

List of Participants

Garcia Garcia, Francisca

Instituto Español de Oceanografía
Spain
paqui.garcia@gi.ieo.es

García-Comas, Carmen

JAMSTEC
Japan
carmencomas@gmail.com

García-Morales, Gisela

CIBNOR
Mexico
ggmorales@cibnor.mx

Garcon, Veronique

Laboratoire d'Etudes en Géophysique et
Océanographie Spatiales
France
veronique.garcon@legos.obs-mip.fr

Gasalla, Maria

University of São Paulo
Brazil
mgasalla@usp.br

Gasol, Josep M

Institut de Ciències del Mar, CSIC
Spain
pepgasol@icm.csic.es

Gattuso, Jean-Pierre

Observatoire Océanologique de
Villefranche-sur-Mer, CNRS-UPMC
France
gattuso@obs-vlfr.fr

Gaxiola, Gilberto

CICESE
Mexico
ggaxiola@cicese.mx

Gehlen, Marion

Laboratoire des Sciences du Climat et de
l'Environnement, IPSL
France
marion.gehlen@lsce.ipsl.fr

Geist, Simon

Leibniz Center for Tropical Marine Ecology
Germany
simon.geist@zmt-bremen.de

Georgian, Samuel

Temple University
USA
georgian@temple.edu

Gessner, Mark

Leibniz Institute of Freshwater Ecology and
Inland Fisheries
Germany
gessner@igb-berlin.de

Ghyoot, Caroline

Université Libre de Bruxelles
Belgium
cghyoot@ulb.ac.be

Giani, Michele

Istituto Nazionale di Oceanografia e di
Geofisica Sperimentale
Italy
mgiani@inogs.it

Giannakourou, Antonia

Hellenic Centre for Marine Research
Greece
agiannak@hcmr.gr

Gipperth, Lena

Swedish Institute for the Marine
Environment
Sweden
lena.gipperth@havsmiljoinstitutet.se

Giske, Jarl

University of Bergen
Norway
jarl.giske@bio.uib.no

Glaeser, Bernhard

German Society for Human Ecology
Germany
bernhardglaeser@gmail.com

List of Participants

Glaser, Marion

Leibniz Center for Tropical Marine Ecology
Germany
marion.glaser@zmt-bremen.de

Godø, Olav Rune

Institute of Marine Research
Norway
olavrune@imr.no

Gogina, Mayya

Leibniz Institute for Baltic Sea Research
Germany
mayya.gogina@io-warnemuende.de

Gogou, Alexandra

Hellenic Centre for Marine Research
Greece
agogou@hcmr.gr

Gomez, Renaud

Laboratoire d'Océanographie et du Climat,
CNRS-UPMC
France
renaud.gomez@locean-ipsl.upmc.fr

Goncalves, Leandra

University of São Paulo
Brazil
goncalvesleandra@gmail.com

Gonzalez, Humberto

Universidad Austral de Chile
Chile
hgonzale@uach.cl

Goris, Nadine

University of Bergen
Norway
nadine.goris@gfi.uib.no

Gorris, Philipp

Leibniz Center for Tropical Marine Ecology
Germany
philipp.gorris@zmt-bremen.de

Gregoire, Marilaure

Université de Liège
Belgium
mgregoire@ulg.ac.be

Groeneveld, Jürgen

Helmholtz Centre for Environmental
Research
Germany
juergen.groeneveld@ufz.de

Gruber, Nicolas

ETH Zurich
Switzerland
nicolas.gruber@env.ethz.ch

Guerrero-Feijóo, Elisa

Instituto Español de Oceanografía
Spain
elisa.guerrero.feijoo@gmail.com

Guillotreau, Patrice

University of Nantes
France
patrice.guillotreau@univ-nantes.fr

Guo, Xinyu

Ehime University
Japan
guoxinyu@sci.ehime-u.ac.jp

Hagen, Wilhelm

University of Bremen
Germany
whagen@uni-bremen.de

Hall, Julie

National Institute of Water and
Atmospheric Research
New Zealand
julie.hall@niwa.co.nz

Haller, Michael

Helmholtz Centre for Environmental
Research
Germany
michael.haller@hzg.de

List of Participants

Hansell, Dennis

University of Miami
USA
dhansell@rsmas.miami.edu

Hansen, Camilla

National Geographic Society
Sweden
chansen@ngs.org

Hansen, Cecilie

Institute of Marine Research
Norway
cecilie.hansen@imr.no

Hardman-Mountford, Nick

CSIRO
Australia
nick.hardman-mountford@csiro.au

Harrison, John

Washington State University
USA
john_harrison@wsu.edu

Hashioka, Taketo

Japan Agency for Marine-Earth Science and
Technology
Japan
hashioka@jamstec.go.jp

Haugan, Peter

University of Bergen
Norway
peter.haugan@gfi.uib.no

Heinze, Christoph

University of Bergen
Norway
christoph.heinze@gfi.uib.no

Heiskanen, Anna-Stiina

Finnish Environment Institute
Finland
anna-stiina.heiskanen@ymparisto.fi

Henson, Stephanie

National Oceanography Centre,
Southampton
UK
s.henson@noc.ac.uk

Herkül, Kristjan

University of Tartu
Estonia
kristjan.herkyl@sea.ee

Herndl, Gerhard

University of Vienna
Austria
gerhard.herndl@univie.ac.at

Hidalgo, Pamela

University of Concepción
Chile
pahidalg@udec.cl

Hill, Simeon

British Antarctic Survey
UK
sih@bas.ac.uk

Hjøllo, Solfrid

Institute of Marine Research
Norway
solfrid.hjollo@imr.no

Ho, Nga Thi Thanh

University of Queensland
Australia
thachnga2002@gmail.com

Hobday, Alistair

CSIRO
Australia
alistair.hobday@csiro.au

Hofmann, Eileen

Old Dominion University
USA
hofmann@ccpo.odu.edu

List of Participants

Holan, Jessica

Australian Antarctic Division
Australia
jrh951@uowmail.edu.au

Holzkämper, Eike Martina

Leibniz Center for Tropical Marine Ecology
Germany
eike_m.h@web.de

Hood, Raleigh

University of Maryland Center for
Environmental Science
USA
rhood@umces.edu

Hoppema, Mario

Alfred Wegener Institute for Polar and
Marine Research
Germany
mario.hoppema@awi.de

Huang , Bangqin

Second Institute of Oceanography, SOA
China
bqhuang@xmu.edu.cn

Huang, Daji

Second Institute of Oceanography, SOA
China
djhuang@sio.org.cn;
dajih2001@yahoo.com

Huggett, Jenny

Oceans and Coasts Research, Department
of Environmental Affairs
South Africa
jenny.huggett@gmail.com

Humphreys, Matthew

National Oceanography Centre,
Southampton
UK
m.p.humphreys@soton.ac.uk

Hung, Chin-Chang

National Sun Yat-sen University
Taiwan
cchung@mail.nsysu.edu.tw

Hung, Jia-Jang

National Sun Yat-sen University
Taiwan
hungjj@mail.nsysu.edu.tw

Hunt, George

University of Washington
USA
geohunt2@uw.edu

Iñiguez Moreno, Concepcion

University of Malaga
Spain
iniguez@uma.es

Iriarte, Jose

Universidad Austral de Chile
Chile
jiriarte@uach.cl

Irigoiien, Xabier

King Abdullah University of Science and
Technology
Saudi Arabia
xabier.irigoyen@kaust.edu.sa

Itoh, Fumihito

University of Tsukuba
Japan
itou30305@ies.life.tsukuba.ac.jp

Jakobsen, Hans H

Aarhus University
Denmark
hhja@dmu.dk

Jeansson, Emil

Uni Research
Norway
emil.jeansson@uni.no

List of Participants

Jeong, Hae Jin

Seoul National University
Republic of Korea
hjjeong@snu.ac.uk

Ji, Rubao

Woods Hole Oceanographic Institution
USA
rji@whoi.edu

Ji, Zhongqiang

Second Institute of Oceanography, SOA
China
jizq@sio.org.cn

Jiao, Nianzhi

Xiamen University
China
jjiao@xmu.edu.cn

Jingjing, Zhang

Second Institute of Oceanography, SOA
China
zhangjingjing0604@hotmail.com

Johannessen, Truls

University of Bergen
Norway
truls@gfi.uib.no

Johnston, Nadine

British Antarctic Survey
UK
nmj@bas.ac.uk

Jones, Burton

King Abdullah University of Science and
Technology
Saudi Arabia
burt.jones@kaust.edu.sa

Jones, Steve

University of East Anglia
UK
s.jones3@uea.ac.uk

Junker, Tim

Leibniz Institute for Baltic Sea Research
Germany
tim.junker@io-warnemuende.de

Kaartvedt, Stein

King Abdullah University of Science and
Technology
Saudi Arabia
stein.kaartvedt@kaust.edu.sa

Kang, Hyoun-Woo

Korea Institute of Ocean Science and
Technology
UK
hwkang@kiost.ac

Karakitsios, Vasileios

University of Athens
Greece
vkarak@geol.uoa.gr

Kattner, Gerhard

Alfred Wegener Institute for Polar and
Marine Research
Germany
gerhard.kattner@awi.de

Kaufman, Daniel

Virginia Institute of Marine Science
USA
dekaufman@vims.edu

Kearney, Kelly

University of Miami
USA
kakearney@gmail.com

Keller, David

GEOMAR
Germany
dkeller@geomar.de

Keller, Kathrin

University of Bern
Switzerland
keller@climate.unibe.ch

List of Participants

Khelifi-Touhami, Meriem

Badji Mokhtar University
Algeria
meriem_khelifi@yahoo.fr

Kidwai, Samina

National Institute of Oceanography
Pakistan
skidwaipk@gmail.com

Kim, Kyungsu

Pukyong National University
Republic of Korea
ks-kim@pknu.ac.kr

King, Andrew

University of Southern California
USA
andrew.king@gmail.com

Kinkade, Danie

Woods Hole Oceanographic Institution
USA
dkinkade@whoi.edu

Knowland, Cheryl

British Antarctic Survey
UK
chenow@bas.ac.uk

Koenigstein, Stefan

University of Bremen
Germany
koenigstein@uni-bremen.de

Kojima, Atsushi

Japan Meteorological Agency
Japan
kojima-ats@met.kishou.go.jp

Koppelman, Rolf

University of Hamburg
Germany
rolf.koppelman@uni-hamburg.de

Korosov, Anton

Nansen Environmental and Remote
Sensing Center
Norway
anton.korosov@nersc.no

Koslow, Julian

Scripps Institution of Oceanography
USA
jkoslow@ucsd.edu

Kosugi, Naohiro

Meteorological Research Institute
Japan
nkosugi@mri-jma.go.jp

Kozyr, Alexander

Carbon Dioxide Information Analysis
Center
USA
kozyra@ornl.gov

Kriest, Iris

GEOMAR
Germany
ikriest@geomar.de

Kristiansen, Trond

Institute of Marine Research
Norway
trond.kristiansen@imr.no

Lachkar, Zouhair

ETH Zurich
Switzerland
zouhair.lachkar@env.ethz.ch

Lahajnar, Niko

University of Hamburg
Germany
niko.lahajnar@zmaw.de

Lamont, Tarron

Oceans and Coasts Research, Department
of Environmental Affairs
South Africa
tarron.lamont@gmail.com

List of Participants

Landolfi, Angela

GEOMAR
Germany
alandolfi@geomar.de

Landschützer, Peter

ETH Zurich
Switzerland
peter.landschuetzer@usys.ethz.ch

Larsen, Aud

University of Bergen
Norway
aud.larsen@bio.uib.no

Lauvset, Siv Kari

University of Bergen
Norway
siv.lauvset@gfi.uib.no

Le Quéré, Corinne

University of East Anglia
UK
c.lequere@uea.ac.uk

Lee, Sung Yeon

Seoul National University
Republic of Korea
cerione@snu.ac.kr

Lefort, Stelly

Laboratoire des Sciences du Climat et de
l'Environnement, IPSL
France
stelly.lefort@lsce.ipsl.fr

Legendre, Louis

Observatoire Océanologique de
Villefranche-sur-Mer, CNRS-UPMC
France
legendre@obs-vlfr.fr

Lehodey, Patrick

Collecte Localisation Satellites (CLS)
France
plehodey@cls.fr

Lekang, Katrine

University of Bergen
Norway
katrine.lekang@bio.uib.no

Li, Qian

Xiamen University
China
liqian00@xmu.edu.cn

Li, Xuefeng

Université Libre de Bruxelles
Belgium
xuefli@ulb.ac.be

Li, Yinji

Tokai University
Japan
riginki@tokai-u.jp

Lien, Vidar S.

Institute of Marine Research
Norway
vidar.lien@imr.no

Lindstrøm, Ulf

Institute of Marine Research
Norway
ulf.lindstroem@imr.no

Liu, Kon-Kee

National Central University
Taiwan
kkliu@ncu.edu.tw

Liu, Su Mei

Ocean University of China
China
sumeiliu@ouc.edu.cn

Liu, W. Timothy

NASA California Institute of Technology
USA
w.t.liu@jpl.nasa.gov

List of Participants

Llopiz, Joel

Woods Hole Oceanographic Institution
USA
jllopiz@whoi.edu

Lo Monaco, Claire

Laboratoire d'Océanographie et du Climat,
CNRS-UPMC
France
claire.lomonaco@locean-ipsl.upmc.fr

Lobanova, Polina

St. Petersburg State University
Russia
pl19@mail.ru

Lorenzo, Maria del Rosario

University of Malaga
Spain
charolg@uma.es

Lotze, Heike

Dalhousie University
Canada
hlotze@dal.ca

Louzao, Maite

Instituto Español de Oceanografía
Spain
maite.louzao@gmail.com

Luchetta, Anna

Istituto di Scienze Marine, CNR
Italy
anna.luchetta@ts.ismar.cnr.it

Luisetti, Tiziana

Centre for Environment, Fisheries &
Aquaculture Science
UK
tiziana.luisetti@cefasc.co.uk

Lundamo, Ingrid

Marine Harvest
Norway
ingrid.lundamo@marineharvest.com

Luo, Genming

China University of Geosciences
China
logming@gmail.com

Lygre, Kjetil

Nansen Environmental and Remote
Sensing Center
Norway
kjetil.lygre@nersc.no

MacIntyre, Geoff

Sea-Bird Scientific
Canada
jrodriguez@seabird.com;
geoff@satlantic.com

Maddison, Lisa

IMBER International Project Office, IMR
Norway
lisa.maddison@imr.no

Mahon, Robin

University of the West Indies
Barbados
rmahon@caribsurf.com

Manno, Clara

British antarctic survey
UK
clanno@bas.ac.uk

Marañon, Emilio

University of Virgo
Spain
em@uvigo.es

Marki, Alexandra

GEOMAR
Germany
amarki@geomar.de

Marques, João Carlos

University of Coimbra
Portugal
jcmimar@ci.uc.pt

List of Participants

Marrasé, Cèlia

Institut de Ciències del Mar, CSIC
Spain
celia@icm.csic.es

Martin, Bettina

University of Hamburg
Germany
bmartin@uni-hamburg.de

Martin, Georg

University of Tartu
Estonia
georg.martin@ut.ee

Martin-Jezequel, Veronique

Université de Nantes
France
veronique.martin-jezequel@univ-nantes.fr

Martins, Catarina

Marine Harvest
Norway
catarina.martins@marineharvest.com

Masumoto, Yukio

University of Tokyo
Japan
masumoto@eps.s.u-tokyo.ac.jp

Mathis, Jeremy

Pacific Marine Environmental Laboratory,
NOAA
USA
jeremy.mathis@noaa.gov

Matsuno, Kohei

National Institute of Polar Research
Japan
k.matsuno@fish.hokudai.ac.jp

Maugendre, Laure

Observatoire Océanologique de
Villefranche-sur-Mer, CNRS-UPMC
France
maugendre@obs-vlfr.fr

Maury, Olivier

Institute for Research and Development
South Africa
olivier.maury@ird.fr

McBride, Margaret

Institute of Marine Research
Norway
margaret.mcbride@imr.no

Mejia, Sandra

European External Action Service, EU
Nicaragua
sandra.mejia@eeas.europa.eu

Melaku Canu, Donata

Istituto Nazionale di Oceanografia e di
Geofisica Sperimentale
Italy
dcanu@ogs.trieste.it

Melbourne-Thomas, Jessica

Antarctic Climate and Ecosystems
Cooperative Research Centre
Australia
jessica.melbournethomas@acecrc.org.au

Memery, Laurent

European Institute for Marine Studies
France
memery@univ-brest.fr

Menden-Deuer, Susanne

University of Rhode Island
USA
smenden@gso.uri.edu

Migon, Christophe

Observatoire Océanologique de
Villefranche-sur-Mer, CNRS-UPMC
France
coppola@obs-vlfr.fr

Milisenda, Giacomo

University of Salento
Italy
giacomo.milisenda@unisalento.it

List of Participants

Minarro Villanueva, Sara

Leibniz Center for Tropical Marine Ecology
Germany
sara.minarro@zmt-bremen.de

Miquel, Juan Carlos

IAEA
Monaco
j.c.miquel@iaea.org

Mitchell, Thomas

Sea-Bird Scientific
USA
tmitchell@seabird.com

Mitra, Aditee

Swansea University
UK
a.mitra@swansea.ac.uk

Mohrholz, Volker

Leibniz Institute for Baltic Sea Research
Germany
volker.mohrholz@io-warnemuende.de

Möllmann, Christian

University of Hamburg
Germany
christian.moellmann@uni-hamburg.de

Moloney, Coleen

University of Cape Town
South Africa
coleen.moloney@uct.ac.za

Montero-Serra, Ignasi

Universitat de Barcelona
Spain
monteroserra@gmail.com

Montes, Ivonne

Geophysical Institute of Peru
Peru
imontes@igp.gob.pe

Morée, Anne

University of Bergen
Norway
anne.moree@gfi.uib.no

Mousing, Erik Askov

University of Copenhagen
Denmark
eamousing@snm.ku.dk

Moutin, Thierry

Mediterranean Institute of Oceanography
France
thierry.moutin@univ-amu.fr

Mueter, Franz

University of Alaska, Fairbanks
USA
fmueter@alaska.edu

Murphy, Eugene

British Antarctic Survey
UK
e.murphy@bas.ac.uk

Murray, Allison

Desert Research Institute
USA
alison.murray@dri.edu

Myksvoll, Mari

Institute of Marine Research
Norway
mari.myksvoll@imr.no

Nakaoka, Shin-ichiro

National Institute for Environmental
Studies
Japan
nakaoka.shinichiro@nies.go.jp

Narvaez, Diego

Old Dominion University
USA
diego@ccpo.odu.edu

List of Participants

Nejstgaard, Jens

Leibniz Institute of Freshwater Ecology and
Inland Fisheries
Germany
nejstgaard@igb-berlin.de

Neuer, Susanne

Arizona State University
USA
susanne.neuer@asu.edu

Newton, Alice

University of Algarve & Norwegian Institute
for Air Research
Norway
anewton@ualg.pt

Nishino, Shigeto

Japan Agency for Marine-Earth Science and
Technology
Japan
nishinos@jamstec.go.jp

Noyon, Margaux

University of Cape Town
South Africa
margauxnoyon@gmail.com

Nummelin, Aleks

University of Bergen
Norway
aleksi.nummelin@gfi.uib.no

O'Brien, Todd

National Marine Fisheries Service, NOAA
USA
todd.obrien@noaa.gov

Obernosterer, Ingrid

Observatoire Océanologique de
Banyuls-sur-mer, CNRS-UPMC
France
ingrid.obernosterer@obs-banyuls.fr

O'Brien, Kevin

National Marine Fisheries Service, NOAA
USA
kevin.m.obrien@noaa.gov

Offre, Pierre

University of Vienna
Austria
pierre.offre@univie.ac.at

Oguz, Temel

METU Institute of Marine Sciences
Turkey
oguz@ims.metu.edu.tr

Olsen, Are

University of Bergen
Norway
are.olsen@gfi.uib.no

Omar, Abdirahman M.

Uni Research
Norway
abdir.omar@uni.no

Onodera, Jonaotaro

Japan Agency for Marine-Earth Science and
Technology
Japan
onoderaj@jamstec.go.jp

Orr, James

Laboratoire des Sciences du Climat et de
l'Environnement, IPSL
France
james.orr@lsce.ipsl.fr

Oschlies, Andreas

GEOMAR
Germany
aoschlies@geomar.de

Österblom, Henrik

Stockholm Resilience Centre
Sweden
henrik.osterblom@stockholmresilience.su.se

List of Participants

Owens, Nicholas

Sir Alister Hardy Foundation for Ocean
Science
UK
sahfos@sahfos.ac.uk

Park, Jisoo

Korea Polar Research Institute
Republic of Korea
jspark@kopri.re.kr

Patricio, Joana

Joint Research Centre, European
Commission
Italy
joana.patricio@jrc.ec.europa.eu

Paul, Allannah

GEOMAR
Germany
apaul@geomar.de

Paulsen, Maria

University of Bergen
Norway
maria.l.paulsen@bio.uib.no

Payne, Mark

National Institute of Aquatic Resources
Denmark
mpay@aqua.dtu.dk

Peck, Myron

University of Hamburg
Germany
myron.peck@uni-hamburg.de

Peck, Victoria

British Antarctic Survey
UK
vlp@bas.ac.uk

Perez Torres, Asvin

Instituto Español de Oceanografía
Spain
asvin.perez@ba.ieo.es

Perry, Ian

University of British Columbia
Canada
ian.perry@dfo-mpo.gc.ca

Peterson, Sarah

University of California, Santa Cruz
USA
saepeter@ucsc.edu

Pfeil, Benjamin

University of Bergen
Norway
benjamin.pfeil@gfi.uib.no

Piñones, Andrea

Yale University
USA
andrea.pinones@yale.edu

Pinto, Rute

University of Coimbra
Portugal
rutepinto@ci.uc.pt

Piola, Alberto

Servicio de Hidrografia Naval
Argentina
apiola@hidro.gov.ar

Planque, Benjamin

Institute of Marine Research
Norway
benjamin.planque@imr.no

Politikos, Dimitrios

IFREMER
France
dimitrios.politikos@ifremer.fr

Popova, Ekaterina

National Oceanography Centre,
Southampton
UK
ekp@noc.ac.uk

List of Participants

Pree, Bernadette

University of Bergen
Norway
bernadette.pree@bio.uib.no

Rabouille, Sophie

Observatoire Océanologique de
Villefranche-sur-Mer, CNRS-UPMC
France
srabouille@obs-vlfr.fr

Rackebrandt, Siri

Oldenburg University
Germany
siri.rackebrandt@uni-oldenburg.de

Radtke, Hagen

Leibniz Institute for Baltic Sea Research
Germany
hagen.radtke@io-warnemuende.de

Rahman, SM Mustafizur

Meteorological Research Centre
Republic of Korea
mustafizraj@gmail.com

Rajasakaren, Balamuralli

Institute of Marine Research
Norway
balamuralli.rajasakaren@imr.no

Ravagnan, Elisa

International Research Institute of
Stavanger
Norway
elisa.ravagnan@iris.no

Ray, Jessica Louise

University of Bergen
Norway
jessicalouiseray@gmail.com

Ray, Raghav

Leibniz Center for Tropical Marine Ecology
Germany
raghav.ray@gmail.com

Rees, Andy

Plymouth Marine Laboratory
UK
apre@pml.ac.uk

Reglero, Patricia

Instituto Español de Oceanografía
Spain
patricia.reglero@ba.ieo.es

Reinthal, Thomas

University of Vienna
Austria
thomas.reinthal@univie.ac.at

Reygondeau, Gabriel

National Institute of Aquatic Resources
Denmark
gabriel.reygondeau@gmail.com

Richards, Russell

Griffith University
Australia
r.richards@griffith.edu.au

Riebesell, Ulf

GEOMAR
Germany
uriebesell@geomar.de

Rios, Aida F.

Instituto de Investigaciones Marinas, CSIC
Spain
aida@iim.csic.es

Rivera, Antonella

Universidad de Oviedo
Spain
rivalidia@uniovi.es

Rixen, Tim

Leibniz Center for Tropical Marine Ecology
Germany
tim.rixen@zmt-bremen.de

List of Participants

Roberts, Michael

Oceans and Coasts Research
South Africa
squid@metroweb.co.za

Robson, Laura

Joint Nature Conservation Committee
UK
laura.robson@jncc.gov.uk

Rödenbeck, Christian

Max Planck Institute for Biogeochemistry
Germany
christian.roedenbeck@bgc-jena.mpg.de

Romero, Sonia

Universidad de Oviedo
Spain
soniarom115@gmail.com

Roura, Ricardo

University of Groningen
The Netherlands
ricardo.roura@worldonline.nl

Roy, Tilla

Laboratoire d'Océanographie et du Climat,
CNRS-UPMC
France
tilla.roy@locean-ipsl.upmc.fr

Ruiz-Ruiz, Thelma

CIBNOR
Mexico
tmruiz@cibnor.mx

Rumin Caparros, Aitor

Universitat de Barcelona
Spain
arumin@ub.edu

Ryabov, Alexey

University of Oldenburg
Germany
alexey.ryabov@uni-oldenburg.de

Rykaczewski, Ryan

University of South Carolina
USA
ryk@sc.edu

Rynearson, Tatiana

University of Rhode Island
USA
rynearson@mail.uri.edu

Sabia, Roberto

European Space Agency
The Netherlands
roberto.sabia@esa.int

Saito, Hiroaki

University of Tokyo
Japan
hsaito@aori.u-tokyo.ac.jp

Saitoh, Sei-Ichi

Hokkaido University
Japan
ssaitoh@salmon.fish.hokudai.ac.jp

Salihoglu, Baris

METU Institute of Marine Sciences
Turkey
baris@ims.metu.edu.tr

Salmon, Elodie

Old Dominion University
USA
elodie.salmon@gmail.com

Salvanes, Anne Gro Ve

University of Bergen
Norway
anne.salvanes@bio.uib.no

Sanchez, Nicolas

Norwegian University of Science and
Technology
Norway
nicolas.sanchez@ntnu.no

List of Participants

Sandaa, Ruth-Anne

University of Bergen
Norway
ruth.sandaa@bio.uib.no

Sanders, Richard

National Oceanography Centre,
Southampton
UK
rics@noc.ac.uk

Santinelli, Chiara

Italian National Research Council
Italy
chiara.santinelli@pi.ibf.cnr.it

Schartau, Markus

GEOMAR
Germany
mschartau@geomar.de

Schlitzer, Reiner

Alfred Wegener Institute for Polar and
Marine Research
Germany
reiner.schlitzer@awi.de

Schmidt, Martin

Leibniz Institute for Baltic Sea Research
Germany
martin.schmidt@io-warnemuende.de

Schukat, Anna

University of Bremen
Germany
schukat@uni-bremen.de

Schuster, Ute

University of Exeter
UK
u.schuster@exeter.ac.uk

Schwinger, Jörg

University of Bergen
Norway
jorg.schwinger@gfi.uib.no

Segovia, Maria

University of Malaga
Spain
segovia@uma.es

Sempéré, Richard

Mediterranean Institute of Oceanography
France
richard.sempere@univ-amu.fr

Serret, Pablo

University of Vigo
Spain
pserret@uvigo.es

Shaltout, Nayrah

National Institute of Oceanography and
Fisheries
Egypt
nshaltout@gmail.com

Shannon, Lynne

University of Cape Town
South Africa
lynne.shannon@uct.ac.za

Shiao, Jen-Chieh

National Taiwan University
Taiwan
jcshiao@ntu.edu.tw

Shigemitsu, Masahito

Hokkaido University
Japan
ma-shige@ees.hokudai.ac.jp

Shiraiwa, Yoshihiro

University of Tsukuba
Japan
emilhux@biol.tsukuba.ac.jp

Silva, Carolina

University of São Paulo & NERSC
Norway
caernani27@gmail.com

List of Participants

Skerritt, Daniel

Newcastle University
UK
d.j.skerritt@ncl.ac.uk

Skjelvan, Ingunn

Uni Research
Norway
ingunn.skjelvan@uni.no

Sloan Ziegler, Jennifer

NOAA Sea Grant Knauss
USA
jennifer.s.ziegler@gmail.com

Smith, Karl

NOAA PMELUSA
karl.smith@noaa.gov

Solidoro, Cosimo

Istituto Nazionale di Oceanografia e di
Geofisica Sperimentale
Italy
csolidoro@inogs.it

Soltwedel, Thomas

Alfred Wegener Institute for Polar and
Marine Research
Germany
thomas.soltwedel@awi.de

Somes, Christopher

GEOMAR
Germany
csomes@geomar.de

Søreide, Janne E.

University Centre in Svalbard
Norway
janne.soreide@unis.no

Steckbauer, Alexandra

Mediterranean Institute for Advanced
Studies, CSIC
Spain
asteckbauer@imedea.uib-csic.es

Stedmon, Colin

Technical University of Denmark (DTU)
Denmark
cost@aqua.dtu.dk

Steele, Deborah

Plymouth Marine Laboratory
UK
dste@pml.ac.uk

Steenbeek, Jeroen

Ecopath International Initiative
Spain
jeroen.steenbeek@gmail.com

Stewart, Joshua

Scripps Institution of Oceanography
USA
j8stewart@ucsd.edu

Stoecker, Diane

University of Maryland Center for
Environmental Science
USA
stoecker@umces.edu

Stoll, Heather

University of Oviedo
Spain
hstoll@geol.uniovi.es

Storesund, Julia Endresen

University of Bergen
Norway
julia.storesund@bio.uib.no

Stramma, Lothar

GEOMAR
Germany
lstramma@geomar.de

Streftaris, Nikos

Hellenic Centre for Marine Research
Greece
nstrefta@hcmr.gr

List of Participants

Strong, James

University of Hull
UK
j.strong@hull.ac.uk

Stübner, Eike

University Centre in Svalbard
Norway
eikes@unis.no

Subramaniam, Ajit

Gordon and Betty Moore Foundation
USA
ajit.subramaniam@moore.org

Sundblad, Eva-Lotta

Swedish Institute for the Marine
Environment
Sweden
eva-lotta.sundblad@havsmiljoinstitutet.se

Sundby, Svein

Institute of Marine Research
Norway
svein.sundby@imr.no

Sweeney, Colm

Earth System Research Laboratory, NOAA
USA
colm.sweeney@noaa.gov

Sweetman, Andrew

International Research Institute of
Stavanger
Norway
andrew.sweetman@iris.no

Tamburini, Christian

Mediterranean Institute of Oceanography
France
christian.tamburini@univ-amu.fr

Tanhua, Toste

GEOMAR
Germany
ttanhua@geomar.de

Tarling, Geraint

British Antarctic Survey
UK
gant@bas.ac.uk

Taucher, Jan

GEOMAR
Germany
jtaucher@geomar.de

Telszewski, Maciej

International Ocean Carbon Coordination
Project (IOCCP)
Poland
m.telszewski@ioccp.org

Tengberg, Anders

University of Gothenburg
Sweden
anderste@chem.gu.se

Therriault, Thomas

Fisheries and Oceans Canada
Canada
thomas.therriault@dfo-mpo.gc.ca

Thingstad, Frede

University of Bergen
Norway
frede.thingstad@bio.uib.no

Thomas, Helmuth

Dalhousie University
Canada
helmuth@phys.ocean.dal.ca

Thorpe, Sally

British Antarctic Survey
UK
seth@bas.ac.uk

Tilbrook, Bronte

CSIRO
Australia
bronte.tilbrook@csiro.au

List of Participants

Tilstone, Gavin

Plymouth Marine Laboratory
UK
ghti@pml.ac.uk

Tim, Nele

Helmholtz Centre for Environmental
Research
Germany
nele.tim@hzg.de

Tittensor, Derek

World Conservation Monitoring Centre,
UNEP
Canada
derek.tittensor@unep-wcmc.org

Tjiputra, Jerry

Uni Research
Norway
jtj061@uni.no

Torn, Kaire

University of Tartu
Estonia
kaire.torn@ut.ee

Torres de Noronha, Isabel

Future Oceans Alliance
Portugal
itnoronha@gmail.com

Townhill, Bryony

Centre for Environment, Fisheries &
Aquaculture Science
UK
bryony.townhill@cefas.co.uk

Tremblay, Luc

Université de Moncton
Canada
luc.tremblay@umoncton.ca

Troedsson, Christofer

Uni Research
Norway
christofer.troedsson@uni.no

Turi, Giuliana

ETH Zurich
Switzerland
giuliana.turi@env.ethz.ch

Tyrrell, Toby

National Oceanography Centre,
Southampton
UK
toby.tyrrell@soton.ac.uk

Uchimiya, Mario

University of Tokyo
Japan
uchimiya@aori.u-tokyo.ac.jp

Ueki, Iwao

JAMSTEC
Japan
uekii@jamstec.go.jp

Urban, Ed

Scientific Committee on Oceanic Research
(SCOR)
USA
ed.urban@scor-int.org

Våge, Selina

University of Bergen
Norway
selina.vage@bio.uib.no

Vallina, Sergio

Institut de Ciències del Mar, CSIC
Spain
vallina@icm.csic.es

Valliyodan, Sudheesh

Cochin University of Science and
Technology
India
sudhikeloth13@gmail.com

van Heuven, Steven

University of Groningen
The Netherlands
svheuven@gmail.com

List of Participants

van Putten, Ingrid

CSIRO
Australia
ingrid.vanputten@csiro.au

Vandromme, Pieter

GEOMAR
Germany
pvandromme@geomar.de

Varela, Marta M

Instituto Español de Oceanografía
Spain
marta.varela@co.ieo.es

Varpe, Øystein

Akvaplan-niva
Norway
oystein.varpe@akvaplan.niva.no

Vedor, Marisa

University of Porto
Portugal
marisavedor@gmail.com

Verissimo Carvalho, Helena

University of Coimbra
Portugal
helenaverissimo@ci.uc.pt

Vidussi, Francesca

Université Montpellier 1
France
francesca.vidussi@univ-montp2.fr

Villanger, Veslemøy

IMBER International Project Office, IMR
Norway
veslemoy@imr.no

Visbeck, Martin

GEOMAR
Germany
mvisbeck@geomar.de

Voelker, christoph

Alfred Wegener Institute for Polar and
Marine Research
Germany
christoph.voelker@awi.de

Vogt, Meike

ETH Zurich
Switzerland
meike.vogt@env.ethz.ch

Waite, Anya

University of Western Australia
Germany
anya.waite@uwa.edu.au

Wakita, Kazumi

Ocean Policy Research Foundation
Japan
kazkazhb@gmail.com

Wallhead, Phil

Norwegian Institute for Water Research
Norway
philip.wallhead@niva.no

Wanninkhof, Rik

Atlantic Oceanographic and Meteorological
Laboratory, NOAA
USA
rik.wanninkhof@noaa.gov

Watermeyer, Kate

University of Cape Town
South Africa
kwatermeyer@gmail.com

Watson, Andrew

Princeton University
UK
andrew.watson@exeter.ac.uk

Watson, James

University of Exeter
USA
james.watson@su.se

List of Participants

Weng, Kevin

University of Hawaii
USA
kweng@hawaii.edu

Werner, Thorsten

Alfred Wegener Institute for Polar and
Marine Research
Germany
thorsten.werner@awi.de

Wiggert, Jerry

University of Southern Mississippi
USA
jerry.wiggert@usm.edu

Xia, Meng

University of Maryland Center for
Environmental Science
USA
mxia@umes.edu

Xu, Yongle

Xiamen University
China
xuyongle3884778@xmu.edu.cn

Yasunaka, Sayaka

JAMSTEC
Japan
yasunaka@jamstec.go.jp

Yi, Xing

Helmholtz Centre for Environmental
Research
Germany
xing.yi@hzg.de

Yoon, Joo-Eun

KIOST
Republic of Korea
eliterem@kiost.ac

Young, Oran

University of California, Santa Barbara
USA
oran.young@gmail.com

Yu, Weidong

First Institute of Oceanography, SOA
China
wdyu@fio.org.cn

Zeng, Qinglu

Hong Kong University of Science and
Technology
China
zeng@ust.hk

Zeri, Christina

Hellenic Centre for Marine Research
Greece
chris@hcmr.gr

Zervoudaki, Sultana

Hellenic Centre for Marine Research
Greece
tanya@hcmr.gr

Zhang, Chuanlun

Xiamen University
China
archaea.zhang@gmail.com

Zhang, Jing

East China Normal University
China
jzhang@sklec.ecnu.edu.cn

Zhang, Zilian

Xiamen University
China
zhangzilian@xmu.edu.cn

Zhao, Liang

Ocean University of China
China
zhaoliang@ouc.edu.cn

Ziveri, Patrizia

Universitat Autònoma de Barcelona
Spain
patrizia.ziveri@uab.cat

List of Participants

Zorita, Eduardo

Helmholtz Centre for Environmental
Research
Germany
eduardo.zorita@hzg.de

Zuo, Fang

IMBER Regional Project Office, ECNU
China
fzuo@sklec.ecnu.edu.cn