# IMBER IMBIZO III

## The future of marine biogeochemistry, ecosystems and societies

**28-31 Jan 2013** — **Goa, India**

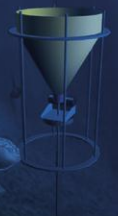
### Workshops

Changing continental margin ecosystems and biogeochemistry

Human impacts and the biological carbon pump

Human-ocean interactions and global change

Conveners : Alida Bundy - Kon-Kee Liu - Julie Hall - Eileen Hofmann
Lisa Maddison - Liana McManus - Wajih Naqvi - Helmuth Thomas



Funded as Oceans EUR-OCEANS CONSORTIUM Conference

**Contact: imbizo@imr.no** **www.imber.info**

Scientific images by Glynn Gorick - glynn@gorick.co.uk / Background illustration & graphic design by Sebastien Herve - contact@sebastien-herve.com


**www.imber.info**

# The future of marine biogeochemistry, ecosystems and societies:

Multi-dimensional approaches to the challenges of global change in continental margins and open ocean systems

28-31 January 2013

Goa, India

**Produced by:** **IMBER International Project Office**
**IMBER Regional Project Office**

**Funded as a** EUR-OCEANS CONSORTIUM **Conference**

## CONTENTS

# IMBIZO III programme

| DAY 1 - Monday 28 January | |
|---|---|
| 08:00-09:00 | IMBIZO lll Registration |
| 09:00-09:15 | Welcome – **Eileen Hofmann, Alida Bundy and Kon-Kee Liu** |
| 09:15-10:00 | Workshop 1 Keynote presentation: Ocean hypoxia from physics to fish – **Curtis Deutsch** |
| 10:00-10:45 | Workshop 1 Keynote presentation: Nutrients, hypoxia and fisheries: lessons about multiple stressors from the Chesapeake and beyond – **Denise Breitburg** |
| 10:45-11:15 | *Coffee break* |
| 11:15-12:00 | Workshop 2 Keynote presentation: Microbial carbon pump and ecosystem connectivity – **Farooq Azam** |
| 12:00-12:45 | Workshop 3 Keynote presentation: "ADApT or Die": finding methodologies to secure the livelihoods and food security for fisheries dependent communities around the world – **Moeniba Isaacs** |
| 12:45-13:45 | *Lunch* |
| 14:45-15:30 | Concurrent workshop sessions |
| 15:30-16:00 | *Coffee break* |
| 16:00-17:00 | Concurrent workshop sessions |
| 17:00-18:00 | **Plenary session discussion – Chair KK Liu, Rapporteur: Karen Wishner**<br>How do biogeochemistry and ecosystems interact in response to natural or man-induced forcing in continental margins and how can such knowledge forge better management of the marine realm? |
| 18:00-19:30 | *Ice breaker and poster session* |

| DAY 2 - Tuesday 29 January | |
|---|---|
| 09:00-10:30 | Concurrent workshop sessions |
| 10:30-11:00 | *Coffee break* |
| 11:00-12:30 | Concurrent workshop sessions |
| 12:30-13:30 | *Lunch* |
| 13:30-15:00 | Concurrent workshop sessions |
| 15:00-15:30 | *Coffee break* |
| 15:30-17:00 | Concurrent workshop sessions |
| 17:00-18:00 | **Plenary session discussion – Chair: Helmuth Thomas**<br>How may current understanding of deep ocean processes translate to better assessment and stewardship of fundamental ecological services that deep oceans provide? |
| 18:00-20:00 | Poster session & BBQ |

| **DAY 3 - Wednesday 30 January** | |
|---|---|
| 09:00-10:30 | Concurrent workshop sessions |
| 10:30-11:00 | *Coffee break* |
| 11:00-12:30 | Concurrent workshop sessions |
| 12:30-13:30 | *Lunch* |
| 13:30-15:00 | Concurrent workshop sessions |
| 15:00-15:30 | *Coffee break* |
| 15:30-17:30 | Concurrent workshop sessions |
| 17:30-18:00 | **Plenary session discussion – Chair: Alida Bundy**<br>How can natural and social scientists optimize their cooperation to achieve usable and integrated knowledge and understanding to support policy making and form viable feedback loops between the natural system and human society? |
| 19:15-24:00 | *IMBIZO lll dinner – Hawaii Beach Restaurant* |

| **DAY 4 - Thursday 31 January** | |
|---|---|
| 09:00-10:30 | Concurrent workshop sessions |
| 10:30-11:00 | *Coffee break* |
| 11:00-12:30 | Concurrent workshop sessions |
| 12:30-13:30 | *Lunch* |
| 13:30-15:00 | **Final Plenary Session**<br>Summary reports from Workshops 1, 2 and 3 and cross-cutting issue sessions |
| 15:00 | Closing comments, End of meeting |

| **Legend** | IMBIZO plenary sessions |
|---|---|
| | Breaks and social activities |

The CSIR-National Institute of Oceanography, Goa is privileged to host, and welcomes the participants in, IMBIZO III convened by the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project during 28-31January, 2013.

The overall theme of IMBIZO III is "*The future of marine biogeochemistry, ecosystems and societies: Multi-dimensional approaches to the challenges of global change in continental margins and open ocean systems*".

Human-induced alterations of the marine environment such as warming, eutrophication, acidification and deoxygenation are expected to cause, if not already causing, large changes in ecosystem functioning and elemental cycling. These changes may not only provide feedbacks to climate change but also have potentially large socio-economic impacts on coastal communities. There are few areas where such changes are expected to be more severe than in the South Asian seas. This is because of their extreme sensitivity to potential perturbations due to unusual conditions they experience (for example, they contain as much as 2/3 of the global continental margin area exposed to low-oxygen bottom waters), as well as the disproportionately large anthropogenic pressure they are subjected to (South Asia accounts for roughly a quarter of the global human population). Thus, the issues to be discussed during IMBIZO III are of great relevance and interest for the region.

We hope that like the previous two IMBIZOs, this event will be highly successful in meeting its objectives. We also hope that the participants will enjoy their visit to Goa, a place of abundant natural beauty and rich cultural heritage, as much as they did in Florida and Crete, the venues of previous IMBIZOs.

**Wajih Naqvi**

Acting Director
CSIR-National Institute of Oceanography, Goa

**Scientific Organising Committee:**

Alida Bundy (Co-Chair): Bedford Institute of Oceanography, Canada

Kon-Kee Liu (Co-Chair): National Central University, Taiwan

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

Eileen Hofmann: Old Dominion University, USA

Lisa Maddison: IMBER International Project Office, Norway

Wajih Naqvi: National Institute of Oceanography, India

Liana Talaue-McManus: Independent Scientist, USA

Helmuth Thomas: Dalhousie University, Canada

**Local Organising Committee:**

*National Institute of Oceanography, Goa, India*

Wajih Naqvi (Chair)
M. Dileep Kumar
P.S. Rao
N. Ramaiah
P. Vethamony
S. Prasanna Kumar
R. Somasunder
V.V. Sanil Kumar
Govind Ranade
Bala Krishna
P. Kumar
A. P. Selvam
Arun Mahale
Siby Kurian
Damodar M. Shenoy
Mangesh Gauns
Hanamant Dalvi
P. M. Muraleedharan
T. Pankajakshan
Bachcha Singh

**IMBER International Project Office (IPO):**

*Institute for Marine Research, Bergen, Norway*

Bernard Avril
Lisa Maddison
Irene Utne

**IMBER Regional Project Office (RPO):**

*East China Normal University, Shanghai, China*

Liuming Hu
Fang Zuo

Integrated Marine Biogeochemistry and Ecosystems Research (IMBER) is an international global change research project that has a goal of understanding the processes underlying ocean responses to accelerating global change to provide predictive capability of the consequent effects on the earth system and human society. Achieving this goal requires identifying key interactions between marine biogeochemical cycles and ecosystems and dependent human societies, and assessing how these interactions respond to complex natural and anthropogenic forcings.

The oceans and marine ecosystems are undergoing fundamental changes. Humans are both a driver and a recipient of this change. As a result, it has become increasingly critical to understand, at scales from local to global, how changes in biogeochemical cycles and ecosystems may affect society and how governments and people should respond and adapt to these changes.

The objective of this third IMBER IMBIZO (a Zulu word meaning 'a gathering') is to bring together scientists from the natural and social sciences to explore the linkages and interactions between human, ecological and biogeochemical systems in the continental margins and open ocean. This objective will be addressed through three overarching questions:

1. How do biogeochemistry and ecosystems interact in response to natural or human-induced forcing in continental margins and how can such knowledge forge better management of the margins?
2. How may current understanding of deep ocean processes translate to better assessment and stewardship of fundamental ecological services that deep oceans provide?
3. How can natural and social scientists optimize their cooperation to achieve usable and integrated knowledge and understanding to support policy making and form viable feedback loops between natural systems and human society?

The format of IMBIZO III consists of three concurrent but interacting workshops. Each workshop includes oral and poster presentations to showcase the current state of knowledge and discussion sessions to identify key questions for future research. Joint plenary and poster sessions provide venues for exchange of ideas and information among the three workshops.

We welcome all participants to IMBIZO lll. We hope that you will enjoy the opportunity to meet and interact with your colleagues, and that each of you will leave with new ideas and a better understanding of human-ocean-human systems.

We thank the CSIR-National Institute of Oceanography in Goa for hosting IMBIZO III and for their invaluable logistical and financial support. We also thank our sponsors (EUR-OCEANS Consortium, IMR, NASA, OCB, PICES, RCN, SCOR, ECNU, SKLEC), whose support made it possible to bring together a diverse group of participants who represent human and natural sciences.

**Council for Scientific and Industrial Research (CSIR)**

The CSIR is India´s largest Research and Development (R&D) organization, with 39 laboratories and 50 field stations or extension centres throughout the country. Its activities include aerospace and structural engineering, ocean sciences, life sciences, metallurgy, chemicals, mining, food, petroleum and the environment. The CSIR aims to provide scientific and industrial R&D that maximises the economic, environmental and societal benefits for the people of India.

**East China Normal University (ECNU)**

ECNU is a key university under the Ministry of Education of the People's Republic of China. The University has 21 schools and colleges and six research institutes that offer undergraduate programs in humanities, education, science, engineering, economics, management, philosophy, psychology, law, history and art, as well as post-graduate and post-doctoral programs.

The **EUR-OCEANS Consortium (EOC)** focuses on the impact of climate/global change on marine ecosystems and biogeochemical cycles, and the construction of scenarios relevant to the emerging International Platform on Biodiversity and Ecosystem Services. It promotes joint initiatives between research and funding organisations to advance the marine sciences. This is done by organising and sponsoring activities, such as IMBIZO lll, which focus on hot topics and can lead to wider European and other projects. IMBIZO lll is funded as a EUR-OCEANS conference.

### Integrated Marine Biogeochemistry and Ecosystem Research (IMBER)

IMBER is an international project, co-sponsored by IGBP and SCOR, that aims to provide increased understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the earth system and human society.

### Institute of Marine Research (IMR)

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 coastal zone. The aim of the research and management advice provided by IMR is to ensure that Norway's marine resources are harvested in a sustainable way. The IMBER International Project Office is hosted by the IMR, at its headquarters in Bergen.

### National Aeronautics and Space Administration (NASA)

NASA is a United States government agency responsible for science and technology related to air and space. The Education Office helps to prepare students who will be the engineers, scientists, astronauts who will continue the exploration of the solar system and universe in years to come. NASA has a tradition of investing in programs and activities that inspire and engage students, educators and communities in exploration.

### National Institute of Oceanography (NIO)

The NIO is one of the 38 laboratories that constitutes the Council of Scientific & Industrial Research (CSIR) in India. With the largest gathering of ocean scientists in the country, and equipped with suitable ocean research infrastructure, NIO serves as an advanced centre of education in ocean sciences. The focus of the research is observing and understanding the special

oceanographic features of the north Indian basin. NIO also provides consultancy on a number of issues including marine environmental protection and coastal zone regulations.

**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. Current members are: Canada, the People's Republic of China, Japan, the Republic of Korea, the Russian Federation, and the USA.

**Ocean Carbon & Biogeochemistry (OCB)**

The USA-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 to inform and advance understanding of ocean biogeochemistry. The program goals are to promote, plan and coordinate collaborative, multidisciplinary research opportunities within the USA research community and with international partners.

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

**Scientific Committee on Oceanic Research (SCOR)**

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.

### State Key Laboratory of Estuarine and Coastal Research (SKLEC)

SKLEC is based at the ECNU in China. Its research areas include: estuarine evolution and sediment dynamics, coastal dynamical geomorphology and sediment processes and estuarine and coastal ecology and environment.

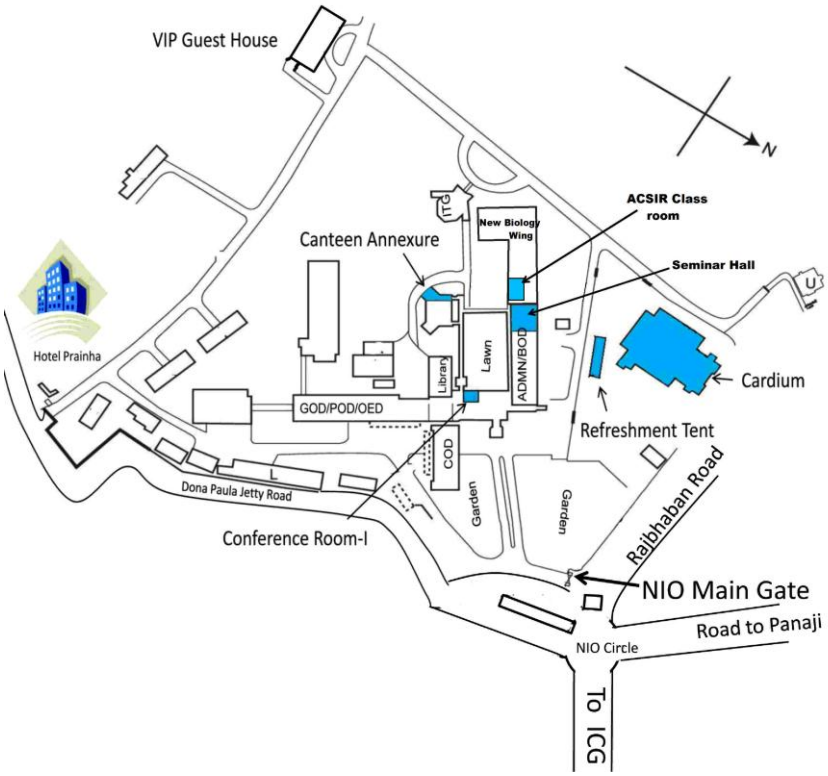
### The Research Council of Norway (RCN)

The Research Council of Norway plays an important role in developing and implementing the country´s national research strategy. It acts as government adviser, identifying current and future needs for knowledge and research. It also funds independent or strategic research programmes and projects at research institutes, and Norwegian participation in international research programmes. It plays a co-ordination role, initiating networks and promoting co-operation between R&D institutions, ministries, business and industry, public agencies and enterprises, other funding sources, and users of research.

## Venue

IMBIZO III will be held at the National Institute of Oceanography (NIO) in Dona Paula, Goa, India.


Map of Goa (see NIO just north of the Hotel Prianha)




Map of NIO. (Blue areas indicate the areas used for IMBIZO lll)

## Address

National Institute of Oceanography
Dona Paula - 403 004, Goa, India
Tel.: +91 (0) 832 - 2450450;
E-mail : ocean@nio.org
For detail information please click HERE

## Registration and information desk

Registration for IMBIZO III is from 08:00-09:00 on Monday 28 January 2013 at the Cardium Hall.
The information desk will remain open for the duration of IMBIZO lll, should you require any assistance or information.
Alternatively, please contact:

- Siby Kurian (siby@nio.org; +91 9423889319)
- Damodar Shenoy (dmhsenoy@nio.org; +91 9422440707)
- Amit Sarkar (amit.sarkar@nio.org; +91 9764246977)
- Bernard Avril (bernard.avril@imr.no; + 47 911 52 835)
- Lisa Maddison (lisa.maddison@imr.no; +47 953 65 708)

## Plenary and workshop venues

Plenary and poster sessions will be held in the Cardium hall.
Venues for three workshops are:
Workshop 1: Seminar Hall
Workshop 2: Conference Room 1
Workshop 3: ACSIR Class Room

## Catering

Please note that breakfast is not provided.
Tea and coffee, and lunch will be served in the Refreshment tent.

## Internet access

Five computers with Internet access are available in the Seminar Hall.
There is WiFi in all workshop venues (code/password will be provided at the Registration desk).

## Social events

An ‘Ice breaker’ (hosted by NIO) will be held in conjunction with the first poster session on 28 January in the vicinity of the Cardium hall from 18:00.

BBQ will be held in conjunction with the second poster session on 29 January, outside the entrance to the Cardium Hall.

The IMBIZO III dinner will be helded on 30/1/2013 from 19:15 onwards at the ‘Hawaii Beach’ restaurant, which is just a short walk (500m) from the NIO. The restaurant is close to the beach and views of the Zuari River, the Dona Paula jetty and the Mormugao harbour.

## Poster instructions

Poster boards will be set up inside the Cardium hall and arranged by workshop in alphabetical order of the presenter's surname.

Participants are responsible for displaying their own posters. They can be put up from 08:00 on Monday 28 January. Please ensure that your poster is up by 18:00 that same evening. The organizers will be available to help you to locate where your poster must be displayed and to provide tape to attach it to the poster boards. The posters will remain on display for the duration of IMBIZO lll.

There are two plenary poster sessions - on the evenings of 28 and 29 January.
A speed presentation of those posters that are not being presented as an oral presentation will take place just before the poster session starts on 28 January. Participants with surnames from A – M are asked to stand with their posters during the first poster session (28 January) and the remainder (N-Z) during the second session (29 January).

### Airport

There are some direct flights to Goa International Airport, but most international flights arrive via Mumbai.

Address: Dabolim-403801
Goa, India
Telephone: +91 832-2540806
+91 832-2541610
Website: www.aai.aero/allAirports/goa_generalinfo.jsp;
en.wikipedia.org/wiki/Dabolim_Airport

### Local Transportation

Pre-paid taxis (yellow cabs) at the airport are recommended, as their rates are slightly cheaper than the white cabs. The cost for a taxi (from the airport to Goa International Center) is about Rs.970 (about US$18) for a non-A/C car and Rs.1100 (about US$20) for an A/C car.

The distances from Goa International Airport to the recommended hotels nearby NIO are as follows:

- International Centre Goa: 30 km
- Prainha Resort: 33 km
- Hotel Fidalgo: 32 km
- Hotel Mandovi: 32 km

### Taxi companies

Booking taxi from the hotel reception is recommended. However, the following taxi companies can also be reached directly:

- MCON Travels: +91 9822100520
- Pundalik: +91 9850443976
- Takshil: +91 9923133193

### Time zone

UTC/GMT +5.30

### Emergency and useful numbers

Emergency services: Police: 100; Medical: 102, 108, Fire: 101.

*Police Station*

- CID Office Dona Paula (50 m from venue)
  Tel: +91 832-2456688
- Goa Police Headquarters, Near Azad Maidan, Panjim, Goa
  Tel: +91 832-2428360 /2428967 /2428267 /2425536

*Local Hospitals*

- NIO-Dispensary (400 m from the venue, inside the NIO residential Campus

With two residential Doctors + Nurses + Pharmacy

- Manipal Hospital, Goa (600 m from the venue)
  Dr. E. Borges Road, Dona Paula, Panaji, Goa 403004
  Tel: +91 832 304 8800
- Goa Medical College (8 km from venue)
  NH 66, Bambolim, Tiswadi, Goa 403202
  Tel: +91 832 2752438

*Ambulance*
+91 832 2453303 /3048800 /2224824 /2458700-07

*Nearest Pharmacies*

- Manipal Hospital, Goa
  Tel: +91 832 3048800
- United Chemist & Druggist, Aiva, Caranzalem, Goa
  Tel: +91 832 2453891
- Nav-Jeevan Chemists & Druggists, Kamat Classic, Caranzalem, Goa
  Tel: +91 832 2461693

*24-hours Pharmacy (7 km from the venue)*
Universal Pharmacy, Mala Panjim, Goa 403001
Tel: +91 832 2223740

**Currency**
The official currency is the Indian Rupee (INR)
(exchange rates on 14 January 2013)
100 INR = 1.14 GBP; 1 GBP = 87.5 INR
100 INR = 1.13 EUR; 1 EUR = 72.7 INR
100 INR = 1.83 USD; 1 USD = 54.5 INR
100 INR = 11.4 CNR; 1 CNR = 8.76 INR

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

**Changing money**
Always exchange your money at a reputable money exchange bureau or bank. There are several currency changing facilities at the Goa International Airport. ATM machines are also available in Dona Paula.

- Bank of Baroda
- Central Bank
- Centurion Bank
- HDFC Bank *
- ICICI Bank *
- UTI Bank
- State Bank of India*

- Bank of India*

**Banks marked with * have ATMs available close to NIO.**

Credit cards (e.g. Visa and MasterCard) are accepted by most hotels and restaurants.

**Tourism Information**

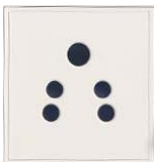
Department of Tourism, Government of Goa, India: www.goatourism.gov.in
Goa Vacation Guide: www.goavacationguide.com/
Goa Tourism Development Corporation www.goa-tourism.com

**Electrical Plugs**

230V (50Hz). Plugs and sockets have either grounded/earthed 3 Pin connections or ungrounded 2 pin connections.

The two pin plug is also called the Europlug. It has two round 4 mm (0.157 in) pins. It can be inserted in either way into the socket. Hence there is no fixed live (hot) and neutral (cold) terminals

The three pin plug is rated at 6A / 250V. It has three round pins in a triangular pattern. The earth terminal is slightly larger than the live and neutral terminals



**Mailing**

India postal office/service: http://www.indiapost.gov.in/

**Weather**

This should be the dry season (October to May), with average temperatures in Goa ranging from 20°C to 32°C during the day, going down to the mid teens at night.
For more information: in.weather.com/weather/10day-Goa-INXX0169; www.weatherforecastmap.com/india/goa/; www.worldweatheronline.com/Goa-weather/Goa/IN.aspx;

# IMBER 'Data Management Training Course and Workshop'

**Sunday 27 January 2013, 09:00-17:00 – NIO Seminar Hall**
**(*held prior to the IMBIZO III*)**

**Workshop conveners**: Cyndy Chandler, Todd O´Brien and Bernard Avril

Welcome to the IMBER 'Data management training course and workshop'!

This one-day workshop will introduce good data management practices highlighting specific recommendations included in the IMBER Data Management Cookbook (www.imber.info/index.php/Science/Working-Groups/Data-Management/Cookbook).
IMBER research projects generate and require access to a large variety of data. For data to be fully used, they must be made available and must also be organized and documented in a way that supports accurate re-use by colleagues. Until recently, IMBER's focus has been mainly on the natural sciences. However its scope also includes the human dimensions of open and coastal waters ecosystems and there is now a need to also plan for the management of social science data (*sensus largo*), and for further integration of datasets from multiple sources and disciplines.

The objectives of this workshop are to enhance awareness of the need to establish data management procedures early in the research process, to highlight the advantages arising when such procedures are followed, and to provide real-world examples of these data management procedures as implemented in IMBER research projects. An additional goal is to cover recommendations specific to management of social science data, and to identify any gaps that might exist in the data management needs of IMBER research projects.

---

09:00
09:15

**Introduction to IMBER – Eileen Hofmann** (Old Dominion University; IMBER SSC Chair)

Our ideas about natural systems and their variability will change over time, as will the most pressing issues that need to be addressed. The data generated by IMBER project researchers are an important part of the IMBER legacy and have great value for research initiatives in the future.

What are the expectations regarding IMBER-related data and is there a need for specific aspects of data management that are not yet provided by IMBER?

---

| | |
|---|---|
| 09:15<br>10:00 | **Dealing with both social and natural science data – Motivation for this IMBER Data Management workshop**<br>• **Sarah Cooley** (Woods Hole Oceanographic Institution; IMBER Human Dimensions WG member) - **Ocean acidification**<br>• **Bob Branton** (Data Management Director, Ocean Tracking Network, OTN) - **Marine fishes**<br>Presentation of case studies relating to these two important IMBER activities that involve both social and natural science data. The challenges and issues that the integration of such data/knowledge creates will be considered. Analysis of lessons learned and opportunities for improved research outcomes or insights. |
| 10:00<br>10:45 | **Why does IMBER need Data Management?**<br>• **Todd O´Brien** (US NOAA, National Marine Fisheries Service; IMBER Data Management Committee member) - **Experience from marine natural sciences**<br>• **Alida Bundy** (Fisheries and Oceans, Canada; Bedford Institute of Oceanography; IMBER Human Dimensions WG Co-Chair) - **Data management for the IMBER Human Dimensions Working Group**<br>Presentations that highlight the benefits of good marine natural and social science data management. |
| 10:45<br>11:15 | **BREAK** |
| 11:15<br>13:00 | **Data management in marine science and other relevant research fields**<br>• **Cyndy Chandler** (US Biological and Chemical Oceanography Data Management Office, BCO-DMO; IMBER Data Management Committee member) - **Marine natural science data management**<br>• **Stéphane Pesant** (PANGAEA – Data Publisher for Earth & Environmental Science, UniHB/MARUM/AWI) - **Marine data integration from -omics to biogeochemistry and ecosystem research**<br>• **Alex de Sherbinin** (Center for International Earth Science Information Network, CIESIN; and NASA Socioeconomic Data and Applications Center, SEDAC) - **Social science data management and data integration for global change research**<br>• **Amy Pienta** (Inter-university Consortium for Political and Social Research, ICPSR) - **Social sciences in an integrated context**<br>Presentations of good data management practices for different types of data/research. Topics discussed will include: data management vocabulary, the basics of metadata, data interoperability, data sharing barriers and opportunities. Reference will be made to the IMBER Data Management Cookbook, the GCMD – IMBER project metadata registration, as well as specific elements related to non-geo-referenced data and personal or statistical human-related data and information. |
| 13:00<br>14:30 | **LUNCH** |

| | |
|---|---|
| 14:30<br>15:30 | **Panel discussion: Panel of experts and practitioners**<br>Key issues identified by panel members and earlier speakers (e.g., metadata, open access, challenges, strategies and solutions for integrating natural and social science data, new data practices, experience sharing) will be discussed, followed by topics and questions raised by the audience.<br>Facilitator: **Bernard Avril** (IMBER Executive Officer) |
| 15:30<br>16:00 | **BREAK** |
| 16:00<br>16:30 | **Open discussion with panellists (continued)** |
| 16:30<br>17:00 | **Conclusion and next steps – Eileen Hofmann**, **Cyndy Chandler**, **Todd O´Brien**<br>Review of the issues raised during the discussion, and possible next steps for the IMBER Data Management Committee. |

# Workshop 1: Biogeochemistry-ecosystem interactions on changing continental margins

**Chair: Kon-Kee Liu**

Shelf sea and continental margin ecosystems, including estuaries, exhibit natural fluctuations in material cycles due to climate variability, but also suffer from anthropogenic stressors of global (such as $CO_2$-induced warming, ocean acidification and enhanced nutrient element transport via the atmosphere), and regional/local impacts (eutrophication/pollution from agriculture and industry in individual watersheds, altered nutrient ratios, coastal hypoxia, intensification of sea floor use, and overexploitation of fish stocks). We need to understand the linear and non-linear responses of biogeochemical and ecological processes to such drivers, which are diverse in the level of disturbance, temporal and spatial scales. This is because they strongly affect the resource value of shelf seas and continental margin systems. Therefore, there is a great deal of societal interest to recognise and possibly manage ecosystem services in a changing world. Our session asks the following overarching questions:

- Can we better understand the dynamics of biogeochemical cycles in continental margin ecosystems by segregating effects of natural forcing variability from long-term trends driven by human actions? (The former are supposedly forced by inter-annual and decadal variability in the regional climate system, while the latter include effects from the ever-increasing anthropogenic $CO_2$ emission, rising SST, shifting hydrological patterns, atmospheric and riverine delivery of anthropogenic nutrients, and direct impacts from pollution, fisheries, energy extraction, invasion, coastal development, etc.)

- Which combinations of natural variability of the external forcing, human-induced environmental changes (e.g. rising sea levels, stratification, and increased storminess), compound effects (e.g. eutrophication enhanced acidification and hypoxia), synergistic interactions, compensating or ameliorating interactions, additive effects, thresholds and tipping points and additional stresses by direct human foodweb manipulation and habitat destruction induce or promote non-linear responses (“regime shifts”) in marine and coastal ecosystems?

Answering these questions entails the clarification of several poorly understood processes, by which modified continental margin ecosystems and material cycles interact and communicate with the open ocean. This includes processes at the sediment-water interface, “memory effects” of past conditions on present status of ecosystems, land-sea fluxes of materials, processes that affect the functioning of the “continental shelf pump” for $CO_2$, and the oxygen status. Especially intriguing is the hysteresis of the watershed-coastal ocean coupled system, which often delays the full

manifestation of adverse as well as remedial effects, and, therefore, warrants special attention.

We have invited contributions on the ecosystem and biogeochemical dynamics of continental margins, how they vary and how they may change in the future due to anthropogenic drivers, and how the changes may feedback to the climate system and threaten the livelihood of the large coastal human population. The session is aimed at promoting awareness of both natural and human-induced changes in continental margin ecosystems and the resulting potential hazards and long-term effects. The discussion is purported to assess threats from various anthropogenic changes imposed upon continental margins and to prioritize future research needs for better assessment. Since not all continental margins are the same, it is highly desirable to identify the most vulnerable continental margins and to specify different types of processes and interactions that are likely to play out on different types of continental margins. Last but not the least we also welcome input and discussion on how such trends may be checked or averted by regulatory measures.

**Workshop 1 Conveners:**

- Kay-Christian Emeis (Helmholtz Center Geesthacht, Germany)
- Lisa Levin (Scripps Institution of Oceanography, USA)
- Kon-Kee Liu (National Central University, Taiwan)
- Wajih Naqvi (National Institue of Oceanography, India)
- Mike Roman (Horn Point Laboratory, USA)

**Workshop 1 Plenary speakers:**

- Curtis Deutsch (University of California, LA, USA)
- Denise Breitburg (Smithsonian Environmental Research Center, USA)

## Workshop 1
## Biogeochemistry-ecosystem interactions on changing continental margins

| DAY 1 - Monday 28 January | |
|---|---|
| 08:00-09:00 | IMBIZO lll Registration |
| 09:00-09:15 | Welcome – **Eileen Hofmann**, **Alida Bundy and Kon-Kee Liu** |
| 09:15-10:00 | Workshop 1 Keynote presentation: Ocean hypoxia from physics to fish – **Curtis Deutsch** |
| 10:00-10:45 | Workshop 1 Keynote presentation: Nutrients, hypoxia and fisheries: lessons about multiple stressors from the Chesapeake and beyond – **Denise Breitburg** |
| 10:45-11:15 | *Coffee break* |
| 11:15-12:00 | Workshop 2 Keynote presentation: Microbial carbon pump and ecosystem connectivity – **Farooq Azam** |
| 12:00-12:45 | Workshop 3 Keynote presentation: "ADApT or Die": Finding methodologies to secure the livelihoods and food security for fisheries dependent communities around the world – **Moeniba Isaacs** |
| 12:45-13:45 | *Lunch* |
| 13:45-14:10 | Workshop 1 overview and objectives - **KK Liu** and **Kay Emeis** |
| 14:10-17:00 | **Session 1 - Chair: KK Liu**<br>**Ecosystem reponses to external forcings in continental margins** |
| 14:10-14:30 | Drivers of change in estuarine-coastal ecosystems: Discoveries from four decades of study in San Francisco Bay, USA - **James Cloern** |
| 14:30-14:50 | Climate-induced ecosystem and biogeochemical shifts in the Cariaco Basin (Venezuela - southeastern Caribbean Sea) - **Enrique Montes** |
| 14:50-15:10 | Nutrient and phytoplankton responses to external forcing in a Mediterranean coastal area unbiased by terrestrial inputs and local activities (Calvi, Corsica) - **Anne Goffart** |
| 15:10-15:30 | Shelves of the Arctic Ocean: C flux and climate change - **Paul Wassmann** |
| 15:30-16:00 | *Coffee break* |
| 16:00-17:00 | **Discussion 1 - Chair: Paul Wassmann, Rapporteur: Eileen Hofmann**<br>**How do biogeochemistry and ecosystems interact in response to climate change or human impacts in continental margins?** |
| 17:00-18:00 | **Plenary session discussion – Chair KK Liu, Rapporteur: Karen Wishner**<br>How do biogeochemistry and ecosystems interact in response to natural or man-induced forcing in continental margins and how can such knowledge forge better management of the marine realm? |
| 18:00-19:30 | *Ice Breaker and poster session* |

| **DAY 2 - Tuesday 29 January** | |
|---|---|
| 09:00-12:30 | **Session 2 - Chair: Karin Limburg**<br>**Human impacts on continental margins** |
| 09:00-09:20 | The North Sea – A shelf sea in the anthropocene – **Kay Emeis** |
| 09:20-09:40 | Role of episodic events in the transport and sequestration of terrestrial sediment in the Cariaco Basin – **Laura Lorenzoni** |
| 09:40-10:00 | Response of nutrient transports to human activities in the ecosystem of the Bohai Sea: Under the influence of artificial floods - **Su Mei Liu** |
| 10:00-10:20 | Eutrophication, nutrient imbalance, ecosystem disruptive algal blooms, and the algal biofuels agenda - **Kevin Flynn** |
| 10:20-10:30 | General discussion |
| 10:30-11:00 | *Coffee break* |
| 11:00-11:20 | The fate of Rhone River carbon on the Mediterranean continental margin, its export to the open sea and its relation to climatic parameters - **Christophe Rabouille** |
| 11:00-12:30 | **Discussion 2 - Chair: Kay Emeis, Rapporteur: Lisa Levin**<br>**What are the characteristics of and early warning indicators for deviations from the regime of natural variability in continental margins due to human impacts?** |
| 12:30-13:30 | *Lunch* |
| 13:30-17:00 | **Session 3 - Chair: Kay Emeis**<br>**Biogeochemical reposes to climate change in continental margins** |
| 13:30-13:50 | To be announced |
| 13:50-14:10 | 210Po/210Pb dynamics in relation to zooplankton biomass and trophic conditions during an annual cycle in northwestern Mediterranean coastal waters - **Jaime Färber Lorda** |
| 14:10-14:30 | Massive nitrogen loss in the seasonal oxygen-deficient zone over the Western Indian - **Amit Sarkar** |
| 14:30-14:50 | Coastal Eastern Arabian Sea? A hotspot for production of nitrous oxide, methane and dimethyl sulphide - **Damodar Shenoy** |
| 14:50-15:00 | General discussion |
| 15:00-15:30 | *Coffee break* |
| 15:30-17:00 | **Discussion 3 - Chair: Curtis Deutsch, Rapporteur: Chuanlun Zhang**<br>**What are the biogeochemical feedbacks from ecosystem responses in continental margins to climate change?** |
| 17:00-18:00 | **Plenary session discussion – Chair: Helmuth Thomas**<br>How may current understanding of deep ocean processes translate to better assessment and stewardship of fundamental ecological services that deep oceans provide? |
| 18:00-20:00 | Poster session & BBQ |

| **DAY 3 - Wednesday 30 January** | |
|---|---|
| 09:00-10:30 | **Session 4 - Chair: KK Liu**<br>**Trends of warming-deoxygenation and their impacts** |
| 09:00-09:20 | In search of the dead zone: Use of otoliths for tracking fish exposure to hypoxia - **Karin Limburg** |
| 09:20-09:40 | Trends in hypoxic conditions in the northern Adriatic Sea - **Michele Giani** |
| 09:40-10:00 | Biogeochemical and environment triggers as hypoxia inducers in the coastal Baltic Sea - **Angela Caballero-Alfonso** |
| 10:00-10:20 | Vulnerability of the Black Sea to human induced environmental pressures under present day conditions and a potential future climate scenario - **Heather Cannaby** |
| 10:20-10:30 | General discussion |
| 10:30-11:00 | *Coffee break* |
| 11:00-12:30 | **Session 5 - Chair: Wajih Naqvi**<br>**Key processes in continental margin biogeochemical cycles** |
| 11:00-11:20 | Si inputs to the world ocean: new insights from the Congo margin and deep sea fan - **Olivier Ragueneau** |
| 11:20-11:40 | Intra-annual variability of nutrient biogeochemistry in the shelf waters off Cochin, southeastern Arabian Sea - **G.V.M. Gupta** |
| 11:40-12:00 | Net anthropogenic nutrient inputs and nutrient fluxes from watersheds - **Dennis Swaney** |
| 12:00-12:20 | Atmospheric deposition of N, P and Fe to the northern Indian Ocean: Implications to surface ocean biogeochemistry – **Manmohan Sarin** |
| 12:20-12:30 | General discussion |
| 12:30-13:30 | *Lunch* |
| 13:30-15:00 | **Session 6 - Chair: Denise Breitburg**<br>**Hypoxia and hypercapnia in upwelling systems** |
| 13:30-13:50 | Hypoxia, hypercapnia and homosapiens on upwelling margins - **Lisa Levin** |
| 13:50-14:10 | The future evolution of multiple stressors in Eastern boundary - **Zouhair Lachkar** |
| 14:10-14:30 | Oxygen minimum zones, zooplankton layers, and global change - **Karen Wishner** |
| 14:30-14:50 | Impacts of seasonal hypoxia on the structure of phytoplankton and mesozooplankton in the water column of the eastern Arabian Sea - **Mangesh Gauns** |
| 14:50-15:00 | General discussion |
| 15:00-15:30 | *Coffee break* |
| 15:30-17:00 | **Discussion 4 - Chair: Denise Breitburg**<br>**How do ecosystems respond to natural or man-induced forcing in continental margins?** |
| 17:00-18:00 | **Plenary session discussion – Chair: Alida Bundy**<br>How can natural and social scientists optimize their cooperation to achieve usable and integrated knowledge and understanding to support policy making and form viable feedback loops between the natural system and human society? |
| 19:15-24:00 | *IMBIZO lll dinner – Hawaii Beach Restaurant* |

| **DAY 4 - Thursday 31 January** | |
|---|---|
| 09:00-10:30 | **Session 7 - Chair: Lisa Levin**<br>**Interactions between natural and social sciences** |
| 09:00-10:30 | **Panel discussion: Human-ocean-human interactions with respect to global change (Workshops 1 and 3 Joint session)** |
| 10:30-11:00 | *Coffee break* |
| 11:00-11:20 | A coupled model of economics, human behaviour, and bivalve biology: application to the surfclam fishery - **Eileen Hofmann** |
| 11:20-12:30 | **Discussion 5 - Chair: Eileen Hofmann, Rapporteur: Karin Limburg**<br>**How can natural scientists provide useful knowledge for better management of continental margin ecosystems?** |
| 12:30-13:30 | *Lunch* |
| 13:30-15:00 | Final plenary session<br>Summary reports from Workshops 1, 2 and 3 and plenary discussion sessions |
| 15:00 | Closing comments |

**Legend:**

| |
|---|
| IMBIZO joint sessions |
| Workshop session themes |
| Joint social activities |
| Discussion sessions |

**DEFORESTATION CAUSES CATASTROPHIC EFFECTS ON TROPICAL CORAL REEFS. VERACRUZ, MÉXICO**.

Virgilio Arenas, D. Salas and M.A. Lozano*

The tropical rivers discharging on the Veracruz Reef System (VRS) transported logs and trees, into the coral reef archipelago of the Gulf of Mexico, composed by more than 20 coral reefs platforms, with a total perimeter by 120 km. All the coral platforms have reef lagoon, with small key or island. The waves and currents in the VRS push big logs and trees of different provenances (jungle, alpine forest, etc), sizes and weights over the reefs causing catastrophic effects. The repeated physical impact on the coral front broke the head of the crests. Eventually the trunks enter the reef lagoon where they kept eroding, and destroying communities, or they remains in the coral front building up important accretions. Surveys shown that on the whole archipelago there are thousands of big logs as a result of older processes of deforestation and landslides. Since 1993 more than 80,000 square kilometers had been deforested on the river watershed and the sediment load has increase from 5 to 60 gr $m^{-3}$ in the last 20 years. Coral reefs develop in response to wave energy, wind stress and currents. They resist hurricanes owing to their structural strength. However, human actions are pushing coral reefs to develop a response to the impact of logs that are no-natural disturbances. The intensification of the deforestation can be considered as a *knock out effect* as it can lead to the ecosystem shift or to the collapses of the reef systems since it may impairs its capacity to recover.

Instituto de Ciencias Marinas y Pesquerías, Universidad Veracruzana. Hidalgo 617, Boca del Rio, Veracruz, México cp. 94294.

Presenting author: arenasvirgilio@yahoo.com

## MACROFAUNAL COMMUNITY STRUCTURE IN THE HYPOXIC ZONE OVER THE WESTERN INDIAN CONTINENTAL SHELF

Shahin Badesab, Zakir Ansari, Siby Kurian, Damodar Shenoy

This study characterizes the macrobenthic gradients over the Western Indian Continental shelf. The coastal Arabian Sea contains the largest shallow water hypoxic systems formed by natural as well as anthropogenic activities. This study is based on the analysis of macrobenthic samples at 22 stations over the western continental shelf of India. A total of 16 groups were identified. The most abundant and frequently occurring group was the Polychaeta, belonging to the families Spionidae, Eunicidae, Cossuridae. The next abundant group was Bivalvia. The contribution of polychaetes was 81.96% to the total macrobenthic density, followed by Bivalvia (6.93%). Amphipoda contributed the least (0.00029%) to the total density. Margalef's Index (d) varied from 0.15- 1.13 over the study area with a higher value at station M8 (110 m) and low values at stations G4 (18 m). The species evenness varied from 0.12-0.76, highest values being at K10 (382m). Further, the value of Shannon-Weiner Index (*H'*) varied from 0.22 - 1.24, the highest being observed at station K3 (33 m). This data will be discussed in relation to environmental characteristics.

National Institute of Oceanography (Council of Scientific & Industrial Research), Dona Paula, Goa, India

Presenting author: sbadesab@nio.org

## SEASONAL VARIATIONS IN $\delta^{15}N$ AND $\delta^{13}C$ OF SUSPENDED PARTICULATE ORGANIC MATTER (SPOM) IN ZUARI ESTUARY, INDIA

Pratirupa Bardhan, Supriya Karapurkar, M.V.Maya, Amit Sarkar, Siby Kurian, Hema Naik, S.W.A Naqvi

Stable isotopes of carbon and nitrogen are considered effective tools to trace sources and transformation pathways of organic matter in estuarine systems. Intra-annual variations in carbon and nitrogen isotopic ratios ($\delta^{15}N$ and $\delta^{13}C$) of suspended particulate organic matter (SPOM) in the water columns of the Zuari estuary along the Indian west coast were measured for the first time at a total of 7 stations from September 2010 to October 2011. Elemental carbon and nitrogen concentrations and C/N ratios in SPOM were also determined for the above-mentioned period. The southwest monsoons have a strong impact on the biogeochemical processes in the Zuari estuary. Moreover, it receives runoff from rice-fields and horticulture plains and serves as pathway for iron and manganese ore transportation. Our results revealed horizontal and seasonal variations in the N and C isotopic composition. During the SW Monsoons, SPOM had higher C:N( >7) and more depleted $\delta^{13}C$ as compared to values before and after its onset; $\delta^{15}N$ showed values intermediate between pre- and post-monsoon regimes – presumably due to enhanced loading of terrestrial OM through land runoff. The mean C:N of the estuary(6.64±0.9,n=42) indicates a planktonic source of the organic matter. For the stations at the mouth end, both $\delta^{13}C$ and $\delta^{15}N$ values show distinct marine signatures while for the other stations, a terrestrial origin may be suggested. We also observed a notable depletion in the $\delta^{15}N$-SPOM and $\delta^{13}C$-SPOM from the marine end (~5.7‰ and ~-21‰ respectively) to the freshwater

National Institute of Oceanography (Council for Scientific and Industrial Research), Dona Paula, Goa-403004, India.

Presenting author: pratirupabardhan@gmail.com

## NITROGEN UPTAKE RATES IN A TROPICAL EUTROPHIC ESTUARY (COCHIN, INDIA)

P.S. Bhavya[1], Sanjeev Kumar[1], G.V.M. Gupta[2], V.Sudheesh[2], D.S.Varrier[2], K.V.Sudharma[2], K.R.Dhanya[2], N.Saravanane[2]

Ammonium, nitrate and $N_2$ uptake rates were measured using $^{15}N$ tracer technique in the tropical eutrophic Cochin estuary, southwest coast of India. *In situ* experiments were conducted at five stations across the salinity gradient within the estuary and one station in the fresh water zone upstream of estuary during April-May 2012 when the region received its first premonsoon rains. Overall, nitrate uptake rates varied from 0.12 to 4.51 mmolN $m^{-3}d^{-1}$ with an average of 2.48 ± 1.48 mmolN $m^{-3}d^{-1}$, whereas ammonium uptake rates were about 4 fold higher and varied from 5.81 to 17.14 mmolN $m^{-3}d^{-1}$ with an average of 11.72 ± 4.39 mmolN $m^{-3}d^{-1}$. In estuarine region, ammonium uptake rates showed strong positive correlation with salinity ($R^2$=0.88), chlorophyll ($R^2$=0.94) and pH ($R^2$=0.69), and moderately with PAR ($R^2$=0.42). This appears to be in concurrence with an earlier mesocosm experiment where reduction in salinity by 4 units resulted into decreased uptake rates. Nitrate uptake rates, however, showed a weak positive correlation with salinity ($R^2$=0.15), which is due to higher nitrate uptake at one particular station with low salinity. Higher than usual light condition at this station (sunny) compared to other stations (cloudy) may be a reason for this. Exclusion of this station resulted into higher $R^2$ (0.61). $N_2$ fixation experiments at these stations did not yield a measurable uptake rate, which is expected due to higher ambient nitrogen concentrations. Overall, it appears that variation in salinity along with light and chlorophyll plays an important role in regulating uptake rates in estuary than the ambient nitrogen concentration.

[1]Physical Research Laboratory, Navrangpura, Ahmedabad, India

[2]Centre for Marine Living Resources and Ecology, Kendriya Bhavan, Kakkanad, Cochin, India

Presenting author: bhavya@prl.res.in

## NUTRIENTS, HYPOXIA AND FISHERIES: LESSONS ABOUT MULTIPLE STRESSORS FROM THE CHESAPEAKE AND BEYOND

Denise Breitburg

Coastal waters worldwide are subject to a variety of stressors related to human activities that potentially affect food webs and fisheries at spatial scales ranging from meters to global coastlines, and temporal scales ranging from minutes to millennia. Both the scales at which stressors act, and the scales at which their actions are evaluated, influence effects that are detected. In Chesapeake Bay, experiments, models and field sampling indicate that combined effects of nutrients, low oxygen and fisheries vary among species, processes, and temporal and spatial scales. Effects of hypoxia on ecologically and economically important fish and shellfish depend on behavioral responses, physiological tolerances, and relationships between these factors and the scales of variability in dissolved oxygen concentrations. Recent experiments and field sampling indicate that even intermittent exposures can affect fish and shellfish growth and disease dynamics. Low pH that often accompanies hypoxia and is predicted to worsen with increasing atmospheric $CO_2$ concentrations, may exacerbate effects of other stressors. Cross-system comparisons provide additional insight into the relationships nutrients, hypoxia and fisheries, and their combined effects on ecosystem structure and services. Developing management strategies to reduce or mitigate stressor effects is difficult without considering the range of co-occurring stressors as well as variability in the natural environment that sets the context in which stressor effects are expressed. Correct identification of stressor-response relationships is also important to developing policies that place a share of the management burden on the various segments of the population that is proportional to undesirable outcomes their activities cause.

Smithsonian Environmental Research Center, Edgewater, MD 20676, USA.

Presenting author: Breitburgd@si.edu.

## BIOGEOCHEMICAL AND ENVIRONMENT TRIGGERS AS HYPOXIA INDUCERS IN THE COASTAL BALTIC SEA

Angela M. Caballero-Alfonso[1*], J. Carstensen[2] and D. Conley[1]

The Baltic Sea has the largest area on the globe with eutrophication-induced hypoxia averaging 49,000 km2 over the last 50 years. In addition, we have identified 115 sites that have experienced hypoxia since 1950s increasing the global total to ca. 500 sites, with the Baltic Sea coastal zone containing over 20% of all known sites worldwide. For the present study, we examined 32 coastal sites with data records extending for 5 decades for long-term trends and seasonal cycles in oxygen concentrations, total nutrients and physical factors. Frequency analysis has shown that most sites have experienced episodic severe hypoxia ([O2]≤2mg/) at different time-scales, which is a precursor to the development of seasonal hypoxia. Results from Generalized Linear Models show that some coastal sites display alarming decreases in oxygen concentrations, but others have also recovered during the last years. Hypoxia is a strong modulator of nutrient biogeochemical processes in both sediment and water, with feedback mechanisms potentially leading to hysteresis responses with environmental factors playing a key role. These complex mechanisms significantly affect coastal ecosystems, including nutrient retention, and shape coastal habitats. Therefore, it is important and relevant to elucidate the influence of both external nutrient loads and environmental factors.

[1] University of Lund, Sweden

[2] Aarhus University, Denmark

Presenting author: Angela.Caballero-Alfonso@geol.lu.se

## VULNERABILITY OF THE BLACK SEA TO HUMAN INDUCED ENVIRONMENTAL PRESSURES UNDER PRESENT DAY CONDITIONS AND A POTENTIAL FUTURE CLIMATE SCENARIO

Heather Cannaby, Bettina Fach, Baris Salihoglu

The vulnerability of the Black Sea to eutrophication, prior to and following the introduction of two invasive species, *Mnemiopsis leidyi* and *Beroe ovate,* has been explored using a coupled hydrodynamic-pelagic ecosystem model. Simulations were performed under present day conditions (1980-1999) and a potential future (2080-2099) climate scenario based on the IPCC A1B projection. Additionally, several 5 year process studies falling within both simulation periods were conducted, using different riverine nutrient loadings corresponding to a range of potential management strategies. The physical structure of the water column changed considerable between the hindcast and forecast periods. A large increase in the heat content of the upper 200 m resulted in a more stable water column and a mean delta change in SST of 3.7 °C. Despite a reduction in nitrate availability at the base of the euphotic zone due to reduced vertical mixing during the forecast simulation, primary production increased by 20 %. This is due to an increased growing season, reduced light limitation on the NW shelf, and increased growth rates. Determination of the relative importance of each of these factors, however, requires further analysis. The response of the Black Sea to changes in riverine nutrient loadings under present day and future climatic conditions was found to be region specific. On the nutrient saturated NW shelf, changes in eutrophication had little impact on primary production. In the mesotrophic central basin however, a 25 % increase/decrease in riverine nutrient loadings resulted in an 18 % increase/27 % reduction in total production. Changes in Danube nutrient loadings are found to impact the entire basin. The impact of eutrophication in the Black Sea appears to be exacerbated by climate warming.

Institute of Marine Sciences, Middle East Technical University,Turkey

Presenting author: heather.cannaby@ims.metu.edu.tr

## DRIVERS OF CHANGE IN ESTUARINE-COASTAL ECOSYSTEMS: DISCOVERIES FROM FOUR DECADES OF STUDY IN SAN FRANCISCO BAY, USA

James Cloern[1] and Alan Jassby[2]

Poised at the interface of rivers, ocean, atmosphere and dense human settlement, estuaries are driven by a large array of natural and anthropogenic forces. San Francisco Bay exemplifies the fast-paced change occurring in many of the world's estuaries, bays and inland seas in response to these diverse forces. We use observations from this well-studied estuary to illustrate responses to six drivers that are common agents of change where land and sea meet: water diversion; river damming; introduction of non-native species; sewage input; environmental policy; and climate shifts. In San Francisco Bay, responses to these drivers include, respectively: shifts in the timing and quantity of freshwater inflow; decreasing turbidity; restructuring of plankton communities; nutrient enrichment; elimination of hypoxia and reduced metal contamination of biota; and food web changes that decrease resistance of the estuary to nutrient pollution. Detection of these changes and discovery of their causes through environmental monitoring have been essential for establishing and measuring outcomes of environmental policies that aim to maintain high water quality and sustain services provided by estuarine-coastal ecosystems. The wide range of variability time scales and the multiplicity of interacting drivers place heavy demands on estuarine monitoring programs. But the San Francisco Bay case study illustrates why the imperative for monitoring has never been greater.

[1]USGS, Menlo Park, California, USA
[2]University of California, Davis, California, USA

Presenting author: jecloern@usgs.gov

**BENTHIC FAUNA OF THE NAMIBIAN SHELF**

Bronwen Currie

The frequent incidence of hydrogen sulphide $H_2S$ on the inner shelf of Namibia's central coast is a characteristic and unique feature. For more than a century hydrogen sulphide events here have been documented to cause death to marine life in the pelagic waters, and these events, associated with severe oxygen depletion in the affected water, continue to be a major threat to the mariculture industry. Extremely high concentrations of $H_2S$ occur in the organic sediments of the central inner shelf, which are densely covered by mats of giant sulphide-oxidizing bacteria *Beggiatoa* and *Thiomargarita* species. Whilst recent research into the microbial processes in the surface sediments has increased our knowledge of formation of the $H_2S$, little is known of benthic faunal distribution, adaptations and responses in this extreme environment. Opportunistic benthic collections on the Namibian shelf sediments between 20ºS and 27ºS over the past four years reveal scanty and small-bodied benthic animals, comprising mainly polychaetes, molluscs, and crustaceans with few echinoderms. Meiofauna comprises abundant nematodes and foraminifera. The distribution of faunal species is examined relative to biogeochemical parameters of overlying water column and surface sediment. Whilst academically interesting, study of the benthic environment and its role to the ecosystem of the northern Benguela Upwelling system is of urgent and critical importance due to intense pressures to remove these sediment layers by dredge-mining Nambia's shelf sediments for phosphates.

National Marine Information and Research Centre, Ministry of Fisheries and Marine Resources
P.O. Box 912, Swakopmund, Namibia

Presenting author: bcurrie@mfmr.gov.na

**CLIMATE, OXYGEN AND MARINE ECOSYSTEMS**

Curtis Deutsch

The warming, acidification, and deoxygenation of the world's oceans represent major perturbations to marine ecosystems and the biogeochemical cycles they engender. The coastal oceans may be especially vulnerable because these global changes are compounded by direct local and regional human impacts.I will present a combination of model simulations and data analysis to demonstrate how climate forces changes in hypoxia and nutrient cycling in the eastern Pacific Ocean, and in the metabolic habitat of coastal species in the Atlantic Ocean. Together, these two case studies illustrate how these factors combine to drive large changes in marine ecosystem processes across oceanic regions with widely different mean states.

University of California, Los Angeles

Presenting author: cdeutsch@atmos.ucla.edu

## THE NORTH SEA – A SHELF SEA IN THE ANTHROPOCENE

Justus van Beusekom[1], Ulrich Callies[1], Ralf Ebinghaus[1], Kay Emeis[1], Andreas Kannen[1], Gerd Kraus[2], Volker Matthias[1], Christian Möllmann[3], Johannes Pätsch[4], Markus Quante[1], Helmuth Thomas[5]

Global and regional change clearly affects material fluxes and the structure and functioning of shelf sea ecosystems. But underlying causes are not readily recognized, and the unambiguous attribution of observed changes to drivers - variability in climate, ocean dynamics, biogeochemistry, and use by human societies - is hindered by complex interactions, short observational time series, and models insufficiently resolved in time, space and complexity. The North Sea is affected by virtually all global and regional change drivers and often at the forefront of developments: Human intervention started 1000 years ago (diking and associated loss of wetlands), spread to near-coastal parts in the industrial revolution of the mid 19th century (river management, waste), greatly accelerated in the mid-1950´s (eutrophication, pollution, fisheries). Natural variability (quasi-cyclic on interannual to multidecadal time scales) is forced by the North Atlantic interacting with secular trends (sea level, temperature, acidification) and variable phases of direct human impact (eutrophication, oligotrophication, re-eutrophication, pollution by traditional and emerging contaminants, fisheries, accelerating use of shelf space). Nowadays, the North Sea is heavily regulated, but societal goals (good environmental status versus increased uses) and policies increasingly diverge; it is likely that much of the southern North Sea will be re-zoned as riparian countries dedicate an increasing amount of sea space to generation of wind energy – with uncertain consequences for the system´s environmental status. We review available observation and model data to identify unambiguous effects of natural variability, secular changes, and human impacts on the North Sea ecosystem, and project these developments into the next decades.

[1]Geesthacht, Germany
[2]vTI-Institute of Sea Fisheries, Palmaille 9, D-22767 Hamburg, Germany
[3]Institute for Hydrobiology and Fisheries Science, University of Hamburg, Grosse Elbstrasse 133, D-22767 Hamburg, Germany
[4]Institute of Oceanography, University of Hamburg, Bundesstraße 53, D-20146 Hamburg, Germany
[5]Dalhousie University , Department of Oceanography , 1355 Oxford Street , PO Box 15000, Halifax, Nova Scotia , Canada, B3H 4R2

Presenting author: kay.emeis@hzg.de

## ZOOPLANKTON SPRING VERTICAL DISTRIBUTION IN THE EASTERN TROPICAL MEXICAN PACIFIC IN RELATION TO OXYGEN AND HYDROGRAPHY.

Jaime Färber Lorda, Emilio Beier, Victor Godinez, Ignacio Romero Vargas Márquez.

Zooplankton samples obtained with a MOCNESS net, from 500m to surface during the PROCOMEX XI cruise to the Mexican tropical Pacific, from 200m to surface 50m layers were sampled. Two east-west transects were followed. In the North, hydrographic conditions were more influenced by the California Current with, lower temperatures and a deeper oxygen minimum (OM) than the southern transect, placed over more tropical waters with more affinity with the Oxygen Minimum Zone (OMZ) and shallower OM. A drastic change was found from ~100m to 500m with lower biomasses and abundances. OM (assuming OM as 45µmoles/Kg.) was deeper in the Northern transect (~90-110m) and shallower in the southern transect (~60-80m). During a 48 hours period of continuous sampling, the vertical distribution of zooplankton showed the same pattern, with diel zooplankton biovolumes differences only in the first 150m and with practically no change in deeper waters. However, small zooplankton (foraminifera and radiolaria) groups were present at all depths, probably reflecting a greater adaptation capacity to low oxygen. Ostracods were restrained to the first 100 m in the entire area with few exceptions, vertical migrators like euphausiids, were present in low oxygenated waters during the day, with 2 well defined peaks, and, within this layer, almost absent in the lowest oxygen concentration layer, and confined to the first 100 m during the night. Surprisingly, copepods were equally abundant during the day than during the night in near surface waters, and also in deep suboxic waters. It is assumed that oxygen acts as a barrier to most zooplankton species, and only small microzooplankton, or highly adapted species like euphausiids and certain copepods, cross this barrier, more studies are necessary to understand this.

CICESE, División de Oceanología. Carr. Ensenada-Tijuana 3918, Ensenada,
B. C. 22860, México.

Presenting author: jfarber@cicese.mx

## DIFFERENCES IN ISOTOPIC SIGNALS BETWEEN SOUTHERN CALIFORNIA CURRENT AND EASTERN TROPICAL PACIFIC EUPHAUSIID SPECIES. POSSIBLE RELATIONSHIP WITH THEIR PHYSICAL AND TROPHIC ENVIRONMENTS.

Färber-Lorda J.[1], Lisa Levin[2], Jennifer Gonzalez[3].

Samples of euphausiids obtained in the Southern California Current and the Mexican tropical Pacific, were analyzed for their isotopic signal in order to evaluate geographic patterns and species-level trophic niche partitioning. The species obtained were *Euphausia diomedeae* and *Euphausia distinguenda*, from the Mexican tropical Pacific and *Euphausia pacifica* and *Thysanoessa spinifera* from the Southern California Current. Within each region each species show a different signal, suggesting distinct feeding preferences. For *E. diomeadeae* higher d15N was obtained, with about equal d13C values for both species, *E. distinguenda* was the dominant species in the area during our autumn (November) sampling. *E. pacifica* and *T. spinifera* also showed a distinct d15N signatures, with heavier values for *T. spinifera*. However, for the latter, only females were obtained during our autumn and winter sampling. In the case of the tropical species, identifiable differences in their morphology might have consequences for their physiology and feeding preferences. The California species, *T. spinifera* and *E. pacifica,* also showed differences in their morphology. *T. spinifera* females exhibited a significant regression with negative slope between carbon and nitrogen in % was found. All the other species exhibited a significant regression between C and N in %, with a positive slope. In general isotopic values are highly variable and the regression between d13C and d15N are not significant, but with a marked greater variability for the California Current species. Work in progress includes the lipid content analyses for each animal and an analysis of the probable relationship of isotopic niche with the morphometrics of all the species studied.

[1]CICESE, Departamento de Ecología. Scripps Institution of Oceanography.

[2]Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, La Jolla CA 92093-0218

[3]Integrative Oceanography Division, Scripps Institution of Oceanography, La Jolla, CA 92093-0218

Presenting author: jfarber@cicese.mx

## $^{210}$PO/$^{210}$PB DYNAMICS IN RELATION TO ZOOPLANKTON BIOMASS AND TROPHIC CONDITIONS DURING AN ANNUAL CYCLE IN NORTHWESTERN MEDITERRANEAN COASTAL WATERS

Färber Lorda, J.[1], S. W. Fowler[2], J. C. Miquel[2], A. Rodriguez y Baéna[2], R. Jeffree[2].

Monthly sampling in northwestern Mediterranean coastal waters was undertaken to better understand the relationship between zooplankton biomass and the cycling of the natural radionuclide $^{210}$Po/$^{210}$Pb pair during a one-year period. $^{210}$Po/$^{210}$Pb measurements in seawater, zooplankton and their fecal pellets were performed. The biochemical composition of particulate organic matter (POM) was also examined at three depths (0, 20 and 50 m) as an indicator of trophic conditions. During May, a strong zooplankton “bloom” was observed which was preceded by a prolonged increase in POM (protein + carbohydrates + lipids) starting at the end of March. Simultaneous measurements of $^{210}$Po in sea water and zooplankton showed an inverse trend during the sampling period; but this relationship was not statistically significant over the entire year. Mesozooplankton and salp fecal pellets, contained $^{210}$Po and $^{210}$Pb levels ranging from 175 – 878 and 7.5 – 486 Bq kg$^{-1}$ dry weight, respectively. Salp pellets contained 5 and 10 times more $^{210}$Po and $^{210}$Pb than in fecal pellets produced by mixed zooplankton, a finding most likely related to their different feeding strategies. During the zooplankton biomass peak, the $^{210}$Po concentration in zooplankton was at a minimum; in contrast to what has been reported to occur in some open sea oligotrophic waters, no statistically significant inverse relationship was found between zooplankton biomass and $^{210}$Po concentration in zooplankton. This observation may have resulted from the general lack of very low biomass concentrations (< 1 mg m$^{-3}$) measured in these coastal waters, biomass levels which commonly occur in open ocean oligotrophic regions.

[1]CICESE, Departamento de Ecología. Carr. Tijuana-Ensenada,

[2]IAEA Marine Environment Laboratories. 4 Quai Antoine 1$^{er}$, MC 98000. Principality of Mónaco.

Presenting author: jfarber@cicese.mx

## EUTROPHICATION, NUTRIENT IMBALANCE, ECOSYSTEM DISRUPTIVE ALGAL BLOOMS, AND THE ALGAL BIOFUELS AGENDA

Kevin J Flynn[1], Aditee Mitra[1], Christopher H Greenwell[2]

With climate change and changes to human population distribution and activity, release of nutrients to the sea from terrestrial sources is expected to change. Further, as sources of phosphate become increasingly limiting, there is a risk that N:P ratios in such releases will become increasingly skewed. These events, especially when coupled with changes in stratification and ocean acidification, are expected to have various implications for marine ecosystems, changing plankton dominance and succession, raising the importance of mixotrophs, changing patterns of POM and DOM production under differential nutrient stresses, and increasing likelihood of ecosystem disruptive algal blooms (EDABs). EDABs alter the flow of nutrients through the system potentially sinking more C, but at the cost of deoxygenation and damage to higher trophic levels. The topic is discussed not only from an angle of physiology and modelling of extant plankton, but also with the spectre of the release of genetically modified (GM) microalgae currently being developed for algal biofuels. GM biofuel-optimised microalgae present a very real risk to ecosystem stability as features required for biofuels production (high growth rate, wide temperature and acidity tolerance, growth at extreme high N:P, high saturated lipid content) will also generate the perfect EDAB species which would be readily spread around the globe. Already GM of microalgae has resulted in changes to fatty acid profiles (altering palatability to grazers) and enhanced photosynthetic efficiency (providing enhanced growth at low light). All these raise the issue of global regulation of GM-microalgae production and of nutrient N:P release.

[1]Centre for Sustainable Aquatic Research, Swansea University, SA2 8PP, UK
[2]Department of Earth Sciences, Durham University, DH1 3LE

Presenting author: k.j.flynn@swansea.ac.uk

## IMPACTS OF SEASONAL HYPOXIA ON THE STRUCTURE OF PHYTOPLANKTON AND MESOZOOPLANKTON IN THE WATER COLUMN OF THE EASTERN ARABIAN SEA

Mangesh Gauns, Sunita Mochemadkar, Anil Pratihary, Gayatree Narvenkar, P. V. Narvekar & S.W.A. Naqvi

A seasonal study was carried out at the Candolim Time Series station located in coastal waters of the eastern Arabian Sea. The data collected include temperature, salinity, dissolved oxygen, chlorophyll *a* and phyto- and mesozoo-plankton taxonomic abundances. The water column over the western continental shelf remains well oxygenated during the non-southwest monsoon periods (November-May). However, upwelling during the SW monsoon (June-October) leads to severe oxygen depletion including sulphate reduction beneath a thin surface layer. The onset of oxygen-deficient conditions affects the productivity and greatly alters the community structure of water-column plankton. Pico-autotrophs were found to dominate the autotrophic biomass. Diatom community was numerically dominated by *Thalassionema, Pseudo-nitzschia, Thalassiothrix, Asterionella, Pleurosigma, Navicula*, *Thalassiosira, Leptocylindrus* and *Rhizosolenia* spp. Among the mesozooplankton, *Acartia* and *Centropages* spp. were found to be associated with anoxia.

National Institute of Oceanography (Council of Scientific & Industrial Research),
Dona Paula, Goa, 403 004, India

Presenting author: gmangesh@nio.org

## TRENDS IN HYPOXIC CONDITIONS IN THE NORTHERN ADRIATIC SEA

Tamara Djakovac[1], Danilo Degobbis[1], Michele Giani[2], Marina Lipizer[2]

Considerable eutrophication pressure in the northern Adriatic sea was caused mainly by increasing anthropogenic nutrient loads during the 1970s and 1980s. However, recent climatic variations also markedly influenced the amounts of nutrients and organic matter and their redistribution in the marine ecosystem and therefore the frequency and intensity of phytoplankton blooms. These variations were characterized by more frequent extreme events of freshwater discharge, increase of sea surface temperature, decrease of atmospheric precipitations, changes in the prevalent winds and consequent changes in the hydrologic cycle and marine circulation pattern. As a major consequence of these variations and enhanced stratification, more frequent reduction of residence time of the bottom layer and unexpected high oxygen consumption in regard to organic production were observed since the late 1980s. Different mechanisms which have determined the extended hypoxic/anoxic events in the northern Adriatic sea were analyzed using long term data series of temperature, salinity, dissolved oxygen and chlorophyll *a* to evidence changes in frequency of hypoxic events in the last decades. In this period after a cluster of near anoxia events in the late 1980s and in early 1990s, hypoxic events (dissolved oxygen concentration $<1.4 \cdot mL\ L^{-1}$) occurred again but without reaching the previous intensity. This is explained by the decreasing trend in the phosphorus load which limits the primary productivity in the Northern Adriatic Sea coupled, particularly during the 2000s, with a decreased rivers discharge.

[1]Center for Marine Research, Rudjer Boskovic Institute, Rovinj, Croatia
[2]Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy

Presenting author: mgiani@inogs.it

## CHANGES OF TROPHIC CONDITIONS IN THE NORTHERN ADRIATIC SEA

Michele Giani[1], Tamara Djakovac[2], Danilo Degobbis[2], Stefano Cozzi[3], Marina Cabrini[1], Cosimo Solidoro[1], Serena Fonda Umani[4]

The northern Adriatic Sea (NAd) is the shallowest, land locked, northernmost part of the Mediterranean Sea. Water column stratification caused by buoyancy input and heat fluxes usually takes place in spring and summer, but intense mixing and water column homogenization regularly occurs during colder seasons, because of the exposure to strong and cold easterly winds and of winter dense water formation. Nutrient inputs from Italian rivers are more concentrated along the western and northern coasts, ,although they can sustain plankton activity over a much more extended area.

Changes in the trophic conditions in the NAd ecosystem have been observed, based on analyses of data time series on riverine discharge rates, oceanographic features, and biological components, collected since the 1970s. A gradual increase of eutrophication pressure occurred during the 1970s up to the mid 1980s, followed by a tendency toward oligotrophication, particularly marked in the 2000s. This tendency was ascribed to the combination of a reduction of the anthropogenic impact (mainly a substantial decrease of the phosphorus load) and climatic variations, resulting in a decline of atmospheric precipitations and, consequently, of the runoff in the NAd watersheds. Significant decreases of the phytoplankton abundances were observed after the mid 1980s, concurrently with changes in the species composition of the communities, with an evident shift to smaller cell or organism sizes.

[1]Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy
[2]Center for Marine Research, Rudjer Boskovic Institute, Rovinj, Croatia
[3]Istituto di Scienze Marine, CNR Trieste, Italy
[4]Dipartimento di Scienze della Vita, Università di Trieste, Trieste, Italy

Presenting author: mgiani@inogs.it

## NUTRIENT AND PHYTOPLANKTON RESPONSES TO EXTERNAL FORCING IN A MEDITERRANEAN COASTAL AREA UNBIASED BY TERRESTRIAL INPUTS AND LOCAL ACTIVITIES (CALVI, CORSICA)

Anne Goffart and Jean-Henri Hecq

Despite its relative oligotrophy, the northwestern Mediterranean exhibits rich pelagic biodiversity and traditional fishing that are fueled by phytoplankton at the basis of the food web. However, long-term observations of phytoplankton blooms exhibit different amplitudes and durations over the years. The mechanisms controlling this variability are still poorly understood, but have implications for the way we study and manage coastal zones in a changing world.

We present a synthesis of a long-term high-resolution study of nutrient and phytoplankton bloom dynamics performed between 1979 and 2011 at a permanent station in the Bay of Calvi (Corsica, northwestern Mediterranean). The ecosystem of the Bay is known to be very sensitive to climate forcing but preserved from local anthropogenic stressors.

As a distinctive feature of the area, the winter-spring phytoplankton bloom of the Bay of Calvi is characterized by a very large interannual variability reaching one order of magnitude from one year to another. In order to understand mechanisms controlling this variability, we defined a winter intensity index (WII) that integrates wind stress intensity and water temperature. WII does not evidence any trend over the 1979 – 2011 period but is closely correlated to nutrient delivery from deep waters and to phytoplankton production. We synthesize our current understanding of phytoplankton response to the combination of external forcing. We also discuss the impact of expected environmental changes on the pelagic food web in a region that is predicted to be particularly sensitive to long-term changes driven by human activities.

University of Liège, Oceanology, 3 allée de la Chimie B6c B 4000 Liège Sart-Tilman Belgium & STARESO BP 33 F 20260 Calvi France

Presenting author: A.Goffart@ulg.ac.be

## CONSEQUENCE OF HUMAN INFLUENCED ENVIRONMENTAL SETTINGS ON PHYTOPLANKTON COMMUNITY STRUCTURE OF ENNORE ESTUARY: AN INTEGRATED MICROSCOPIC AND SIZE FRACTIONED CHLOROPHYLL *a* STUDY.

Prasun Goswami[1], Nallamuthu Godhantaraman[2], Natesan Munuswamy[1]*

The dynamics of phytoplankton community were investigated in an industry influenced estuary (Ennore, SE coast of India) and its adjacent coastal sites of Bay of Bengal from May 2011to April 2012. Three distinct size classes i.e. Microplankton (>20µm), nanoplankton (2-20µm) and picoplankton (0.2-2 µm) were selected and their biomass in terms of Chlorophyll *a* (Chl*a*) were analyzed along with microscopic enumeration for species composition. Nutrient concentrations like nitrate, nitrite, phosphate, silicate and ammonia were observed very high at estuary compared to coastal site throughout the year as it receives substantial amount of semi-treated and/or untreated industrial and anthropogenic loads from Kortalaiyar River and Buchingham canal. High nutrient concentrations trigger proliferated phytoplankton biomass as the maximum total Chl*a* was observed 82.5 µg/L at estuarine site during December, 2011. The variation of total Chl*a* was in the range of 3.06- 26.4 µg/L (avg. 15.59±9.63 µg/L) at coastal site and 5.59- 82.5 µg/L (avg. 41.84± 33.1 µg/L) at estuarine site. Size fractioned chl*a* revealed microplankton was the most dominant group in this estuary ranges in between 49.1%-94.63% of total composition. But the situation changed dramatically during March, 2012 when picoplankton was most dominant group (63.94%) followed by nanoplankton (22.63%). This was the response of comparative low nutrient availability and increase in turbidity. Microscopic study revealed diatom was the most dominating group, represented by *Coscinodiscus* spp., *Navicula* sp., *Skeletonema* sp., *Chaetoceros* sp., followed by dinoflagellate and cyanobacteria. Hence, the present study revealed mesotrophic condition of Ennore estuary due to high nutrient stoichiometry.

[1]Unit of Aquaculture and Cryobiology, Department of Zoology, University of Madras. Chennai- 600025, India.
[2]UGC Academic Staff College, University of Madras. Chennai- 600005, India.

Presenting author: prasun.goswami@gmail.com
*Author of correspondence: munuswamynm@yahoo.com

## INTRA-ANNUAL VARIABILITY OF NUTRIENT BIOGEOCHEMISTRY IN THE SHELF WATERS OFF COCHIN, SOUTHEASTERN ARABIAN SEA

G.V.M.Gupta*, N.Saravanane, A.Shivaji, V.Sudheesh, K.V.Sudharma, D.S.Varrier, G.Lakshmi, K.R.Dhanya, R.M.Antony, T.P.Maneesh

Monthly observations between January and July 2012 in the shelf waters (up to 100 m) of Cochin, southeastern Arabian Sea showed clear seasonality involving sinking of warm oligotrophic surface waters during winter monsoon (WM) and upwelling of oxygen deficient nutrient rich cold waters during summer monsoon (SM). The upwelling initiated in the deep layers during March could reach the surface in two months (May), thereafter it established over the entire shelf by July. Nutrient concentrations (except ammonia) increased greatly from January to July and followed inversely with the variations of dissolved oxygen and ammonia. The substantial enrichment of nutrients during SM seems to be driven mainly by upwelling since the terrestrial inputs, at least during early stages of monsoon, were considerably low due to weak monsoon followed by *El Nino* conditions. The progressive injection of nutrients into the surface layers were tightly coupled in promoting the phytoplankton production that bloomed by June corroborating >4 fold rise in chlorophyll concentration between May and June. The blooming of phytoplankton leading to autotrophy in the surface during peak upwelling (June-July) was concomitant with a shift in trophic status to heterotrophy in the sub-surface, the latter was due to the combined effects of poor primary production, limited by light intensity following monsoon clouds, and elevated bacterial respiration. Overall, the trophic status is suggestive of a progressive switch over from autotrophy (>1) to heterotrophy (<1) following the monsoon upwelling. Thus, bacterial biomass and activity which are low during early phases of upwelling became increasingly important in controlling the nutrient biogeochemistry of the region as the upwelling intensity increases.

Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, Kendriya Bhavan, Kakkanad, CSEZ P.O., Cochin-682037, India

Presenting author: gvmgupta@gmail.com

## A COUPLED MODEL OF ECONOMICS, HUMAN BEHAVIOR, AND BIVALVE BIOLOGY: APPLICATION TO THE SURFCLAM FISHERY

Eileen E. Hofmann[1], John M. Klinck[1], Bonnie McCay[2], Carolyn Creed[2], Sylvia Brandt[3], Cesar Marcelo Viteri Mejia[3], Eric N. Powell[4], Daphne Munroe[5], Dale B. Haidvogel[6], Roger Mann[7]

The Atlantic surfclam (*Spisula solidissima*) along the continental shelf of the Middle Atlantic Bight (MAB) region of the U.S. east coast supports an important commercial fishery. Climate-induced warming of bottom temperatures along the southern part of the surfclam range has impaired growth and reproduction, producing a decline in biomass. To investigate the effects of changing environmental conditions on this fishery, a modeling framework has been developed that includes the physical environment, larval and post-settlement surfclam biology, and fishery economics. The physical environment is simulated using a version of the Regional Ocean Modeling System (ROMS), which provides simulations of the circulation and bottom temperature fields that are then input to models of surfclam larvae growth and behavior and post-settlement population dynamics. The larval simulations showed the importance of behavior in retaining surfclam larvae in inner shelf regions of the MAB. The detrimental effect of warming bottom temperatures on simulated growth and reproduction of post-settlement surfclams was most pronounced in the southern part of the range. The fishery economics model considered the costs and benefits of harvesting surfclams in terms of the relative distribution of fishing effort versus the shifting distribution of the resource. The simulations showed that warming bottom temperatures have an economic effect on the surfclam fishing fleet in the southern part of the range because the increased time and distance needed to harvest resource increases the overall cost and reduces profits. Management of this species needs to consider the shifting distribution of the resource.

[1]Center for Coastal Physical Oceanography, Old Dominion University, Norfolk, VA 23508 USA
[2]Department of Human Ecology, School of Environmental & Biological Sciences, Rutgers the State University, 55 Dudley Road, New Brunswick, NJ 08901 USA
[3]Department of Resource Economics, 205A Stockbridge Hall, University of Massachusetts, Amherst, MA 01003 USA
[4]Gulf Coast Research Laboratory, University of Southern Mississippi, 703 East Beach Drive, Ocean Springs, MS 39564 USA
[5]Haskin Shellfish Research Laboratory, Rutgers University, 6959 Miller Avenue, Port Norris, NJ 08349
[6]Institute of Marine and Coastal Science Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901-8525 USA
[7]Virginia Institute of Marine Science, Gloucester Point, VA 23062 USA

Presenting author: hofmann@ccpo.odu.edu

## YEAR-TO-YEAR VARIABILITY OF CHLOROPHYLL-A IN RELATION WITH MIXED LAYER DEPTH CHANGES IN THE EAST SEA (JAPAN SEA)

Chan Joo Jang, Jihyeon So, Taewook Park and Sinjae Yoo

We examine year-to-year variability of springtime chlorophyll-a (CHL-a) concentration in association with ocean mixed layer depth (MLD) in the East Sea (Japan Sea) by analysing monthly-mean data of MLD (1/12° Global HYbrid Coordinate Ocean Model (HYCOM)), and of satellite (SeaWiFS and MODIS) CHL-a for the period (2004-2010). The spring CHL-a concentration shows substantial year-to-year variability. In 2008, CHL-a concentration in the Ulleung basin in April reaches a maximum (8 times larger than the other years) for the period (2004-2010). The increase of the spring CHL-a concentration in 2008 is attributed to considerable deeper winter mixed-layer (about 2 times larger than normal years) that probably entrains more deep-ocean nutrients into the upper ocean, making favorable spring bloom condition. The larger winter MLD in 2008 is caused by intensified wind and ocean surface cooling that are associated with strengthened Siberian high and Aleutian low. On the other hand, spring CHL-a in 2004 is not elevated significantly, although the winder MLD deepens considerably. We will present possible mechanisms (different springtime stratification, circulation, and available nutrients etc.) to explain the difference responses of the phytoplankton to MLD changes.

Korea Institute of Ocean Science & Technology, Ansan, 426-744, Republic of Korea

Presenting author: cjjang@kiost.ac

## DENITRIFYING COMMUNITIES IN OCEANIC OXYGEN DEFICIENT ZONES USING MICROARRAY ANALYSES

Amal Jayakumar, Nick Peng and Bess Ward

Cycling of Nitrogen, a key element in biogeochemical processes, has been altered due to anthropogenic activities. The past few decades have witnessed the expansion of coastal hypoxia, related to agriculture and urbanization, and of open ocean Oxygen Minimum Zones (OMZ), possibly related to global warming. OMZs and specifically Oxygen Deficient Zones (ODZ) are sites of intense N transformations by microbes, leading to removal of N from the ecosystem by denitrification and anammox. With the predicted intensification and expansion of ODZs, it is important to understand microbial community composition, dynamics, and regulation in the ODZs. We have developed a functional gene microarray to evaluate the diversity and composition of the denitrifying community by targeting the nirS gene, which encodes the key gene in the denitrification pathway. The customized microarray contains a suite of 165 *nirS* archetype probes (each representing sequences < 15% divergence) designed from all available *nirS* sequences. Community composition was compared for archetypes that contributed > 1% of the total fluorescence signal in the Arabian Sea ODZ and Eastern Tropical South Pacific (ETSP) ODZ. *nirS* assemblages in both ODZs were significantly different from *nirS* assemblages in previously explored estuarine environments. Assemblages differed both regionally (ETSP vs AS) and with depth (ODZ vs euphotic zone samples) in both regions. Within the ETSP, assemblages showed geographic trends (northern vs southern stations and coastal vs offshore). This relatively high throughput method for characterizing natural assemblages should allow us to detect microbial community changes in response to environmental change in the coming decades.

Guyot Hall, Geosciences, Princeton University, Princeton, NJ, USA

Presenting author: ajayakum@princeton.edu

## THE FUTURE EVOLUTION OF MULTIPLE STRESSORS IN EASTERN BOUNDARY UPWELLING SYSTEMS

Zouhair Lachkar and Nicolas Gruber

Eastern Boundary Upwelling Systems (EBUS) such as the California Current System (California CS) and the Canary Current System (Canary CS) are highly productive marine ecosystems undergoing increasing stress levels driven by global environmental changes. EBUS naturally experience low pH and low $O_2$ due to upwelling of $CO_2$ enriched, $O_2$ depleted waters from depth. This makes these systems particularly vulnerable to global perturbations such as ocean acidification and ocean deoxygentation. The severity of these chemical perturbations may further be exacerbated by concurrent climate change driven perturbations such as enhanced vertical stratification and increased upwelling-favorable winds. Here we study the cumulative and interactive effects these multiple stressors may have on EBUS ecosystems and explore their combined potential impacts on the habitat size of $O_2$- and $CO_2$- sensitive species. To this end, we undertook a series of idealized perturbation studies with eddy-resolving setups of the Regional Oceanic Modeling System – ROMS– to which a nitrogen based Nutrient-Phytoplankton-Detritus-Zooplankton (NPDZ) biogeochemical model was coupled. These idealized perturbations include i) increased $CO_2$, ii) increased upwelling-favorable winds, and iii) increased surface temperatures. Our model simulations show that ocean acidification in EBUS is primarily driven by the rise of atmospheric $CO_2$, while warming, stratification, and local wind changes have a much smaller impact. In contrast, ocean deoxygenation is quite sensitive to physical perturbations, but with large differences between the two investigated EBUS, likely reflecting underlying differences in the processes that govern regional oxygen balance. Initial results also reveal that the upwelling intensification and surface warming drive opposing changes in coastal hypoxia and $CaCO_3$ undersaturation, potentially compensating each other when occurring concurrently.

Environmental Physics Group, Institute of Biogeochemistry and Pollutant Dynamics, ETH Zurich, Zürich, Switzerland.

Presenting author: zouhair.lachkar@env.ethz.ch

## HYPOXIA, HYPERCAPNIA AND HOMOSAPIENS ON UPWELLING MARGINS

Lisa A. Levin, Christina Frieder, Michael Navarro, Jennifer Gonzalez, Todd Martz

Benthic assemblages on upwelling margins experience especially strong gradients in temperature, oxygen and $CO_2$ over a range of time and space scales. As oxygen minimum zones expand from below and acidification and euthrophication encroach from above, the upper continental margins will be subject to increasing environmental stress. Understanding integrated biotic responses to these gradients and stressors can reveal how future climate change may affect key ecosystem functions and services provided by margins. Both mensurative and manipulative approaches offer insight. Here we will employ benthic data to separate effects of hypoxia from hypercapnia on community structure and function in the world oxygen minimum zones, (ii) examine the high-frequency dynamics of oxygen and pH variation on upwelling margins margin and (iii) experimentally evaluate effects on invertebrate development. Consequences include changes in emergent properties of margin ecosystems such as productivity, biodiversity, resilience, and connectivity as well as carbon sequestration and nitrogen cycling. We face a major challenge to incorporate both natural and climate-induced variability of hypoxia and hypercapnia into management of nutrient inputs, fishing, energy extraction and mining on the world's outer shelf and upper slope environments.

Scripps Institution of Oceanography, La Jolla, CA 92093-0218

Presenting author: llevin@ucsd.edu

## IN SEARCH OF THE DEAD ZONE: USE OF OTOLITHS FOR TRACKING FISH EXPOSURE TO HYPOXIA

Limburg, K.E

Otolith chemistry is often useful for tracking provenance of fishes, as well as examining migration histories. Whereas elements such as strontium and barium correlate well with salinity and temperature, experiments that examine manganese uptake as a function of these parameters have found no such correlation. Instead, dissolved manganese is available as a redox product, and as such, is indicative of low-oxygen conditions. Here I present evidence for that mechanism in a range of habitats from marine to freshwater, across species, and also present ancillary proxies that support the mechanism as well. The implication of this research is that there is now a way to identify individual fish exposure to hypoxia, over its entire lifetime. Further, fish may be able to be used as “mobile monitors” of hypoxic conditions.

Dept. of Environmental and Forest Biology, State University of New York College of Environmental Science & Forestry, Syracuse, NY 13210 USA.

Presenting author: KLimburg@esf.edu

## IMPACTS OF ANTHROPOGENIC NUTRIENTS ON THE OXYGEN DEMAND IN THE BOTTOM WATER OF THE EAST CHINA SEA AND POTENTIAL RISKS OF HYPOXIA

K.-K. Liu[1], H.-J. Lee[2], S.-Y. Chao[3], G.-C. Gong[2], Y.-C. Teng[4], T.-Y. Yeh[1]

Anthropogenic sources contribute a major portion of riverine loads of nutrient discharged to the coastal ocean. Recently it was demonstrated that the nitrogen input to the Changjiang watershed increased by 3 fold in the last four decades and the nitrogen load had grown exponentially. We employ a coupled 3-D physical-biogeochemical model of the East China Sea to investigate how the anthropogenic nutrient loads affect primary productivity and the consequences of altered oxygen demand in the bottom water. The preliminary model results reveal a non-linear response of the benthic oxygen consumption rate to the exponentially increasing Changjiang nitrogen loading. The effects of the anthropogenic contribution to the nitrogen load on primary production, benthic oxygen demand and denitrification are evaluated and areas of potential hypoxia development are explored.

[1]National Central University, Jungli, Taiwan ROC
[2]National Taiwan Ocean University, Keelung, Taiwan ROC
[3]Horn Point Lab, UMCES, Cambridge, MD
[4]Virginia Institute of Marine Science, Gloucester Point, USA (ycteng@vims.edu)

Presenting author: kkliu@ncu.edu.tw

## ROLE OF EPISODIC EVENTS IN THE TRANSPORT AND SEQUESTRATION OF TERRESTRIAL SEDIMENT IN THE CARIACO BASIN

Lorenzoni, Laura[1,*], Claudia R. Benitez-Nelson[2,3], Robert C. Thunell[2,3], David Hollander[1], Ramón Varela[4], Yrene Astor[4] and Frank E. Muller-Karger[1]

Lithogenic sediment input in the Cariaco Basin (Venezuela) is controlled by small mountainous rivers (SMR), which reach peak discharge during September. The SMR in Cariaco also have the capacity to deliver large amounts of sediment to the Cariaco Basin during episodic events, such as earthquakes and floods. Event-driven downslope mobilization of sediment is an important means of continental OC sequestration and burial. Several episodic events have been indirectly observed in the basin in response to climatic (i.e. floods) or tectonic events. Here we present an example of flood-driven and one of tectonically-triggered sediment transport into the Cariaco Basin. Each of these events has transported to the deep basin >10% of the average annual sediment flux to the seafloor of the Cariaco Basin, making them an important local sedimentary sink. The rapid means that flood- or earthquake-triggered sediment flows reach the deeper portions of the basin (either via bottom nepheloid layers / hyperpycnal flows or by direct funneling to the deep via submarine canyon) has also important implications for the rapid transport and burial of terrestrially-derived organic carbon. Climate models predict higher precipitation over northern South America; this does not imply more episodic flooding events, but it does suggest longer rainy seasons, which could increase the transport of sediment and terrestrially-derived organic matter into the basin. This would be analogous to very warm conditions observed in the paleoclimatic record, where a more northerly position of the Intertropical Convergen Zone enhanced the transport of continental material into the basin.

[1]College of Marine Science, University of South Florida, St. Petersburg, Florida, 33701. USA
[2]Department of Earth & Ocean Sciences, University of South Carolina, Columbia SC 29208. USA
[3]Marine Science Program, University of South Carolina, Columbia SC 29208. USA
[4]Estación de Investigaciones Marinas de Margarita (EDIMAR), Fundación La Salle de Ciencias Naturales (FLASA), Isla de Margarita, Venezuela

Presenting author: laural@mail.usf.edu

**MOLECULAR DIVERSITY AND ECOLOGICAL IMPLICATIONS OF FUNGI IN THE OXYGEN DEPLETED ENVIRONMENTS OF THE ARABIAN SEA.**

Kesava Priyan Ramasamy and Cathrine Sumathi Manohar

Fungi play a key role in the decomposition and biochemical transformation of organic matter in the marine habitat. They are actively involved in the C and N cycle and aid in the release of the inorganic nutrients back into the ecosystem. However, they were considered to play only a minor role in the ecosystem processes when there is an oxygen deficiency. Studies on the fungal diversity from the Arabian Sea region has shown that fungal abundance has a positive correlation with the changing dissolved oxygen levels in the coastal oxygen-depleted environments (ODEs). Molecular analysis of the unculturable diversity of fungi has shown that there is a vast and novel diversity in the marine ODEs. Though, there are no direct evidence of their ecological role in the ODEs, studies have shown that many members of kingdom fungi have physiological adaptations to thrive in environments with varying oxygen concentrations. Many fungal taxa are shown to possess metabolic adaptations to utilize nitrate and (or) nitrite as an alternative for oxygen. But the molecular basis on how the members of Kingdom Fungi acquired the ability is still unknown. The novel and diverse fungal diversity reported from the various marine ODEs and the growth characteristics of the culturable fungi will be discussed.

CSIR-National Institute of Oceanography, Dona Paula, Goa 4003004, India.

Presenting author: cathrine@nio.org

## CLIMATE-INDUCED ECOSYSTEM AND BIOGEOCHEMICAL SHIFTS IN THE CARIACO BASIN (VENEZUELA - SOUTHEASTERN CARIBBEAN SEA)

Enrique Montes[1], Frank E. Muller-Karger[1], Gordon Taylor[2], Robert C. Thunell[3], Laura Lorenzoni[1], Digna Rueda-Roa[1], Yrene M. Astor[4], Ramón Varela[4]

Understanding how marine ecosystems are influenced by climate variability requires long-term global observations. We have identified marked and concurrent changes in ecosystem state and biogeochemical cycles in the southeastern Caribbean Sea (Venezuela) at the CARIACO Ocean Time-Series (10.5N, 64.66W). This time-series program has been collecting monthly oceanographic and biogeochemical measurements since 1995 with the aim of understanding the linkages between hydrography, community composition, primary production, particle fluxes, and water column elemental cycling, how variations in these processes are connected to climatic variations, and ultimately how climatic signals are preserved in the sediments. The CARIACO site has recorded a decrease in diatom abundance, while nano- and pico-phytoplankton, and zooplankton biomass, have increased concurrently. Chlorophyll *a* and net primary productivity have decreased at a rate of -2.8 ± 0.5 and -1.5 ± 0.3% $yr^{-1}$, respectively. Upper mixed layer N* has been increasing (~0.09 μM $yr^{-1}$), suggesting that diazotrophic activity has accelerated within the Caribbean Sea and the regional North Atlantic. This observation coincides with an upward trend in the abundance of *Trichodesmium thiebautii* in the basin. Furthermore, top-down controls on the ecosystem have been exerted by a near-complete collapse of the Spanish sardine (*Sardinella aurita*) fishery off NE Venezuela. We attribute these ecosystem and biogeochemical changes to a decrease in coastal upwelling intensity and higher thermal stratification due to the weakening of the Trade Winds (-1.9% $yr^{-1}$) and a steady increase in sea surface temperature (>1.0°C since 1995). These climatic changes are coincident with a northward migration of the inter-tropical convergence zone.

[1]College of Marine Science, University of South Florida, St. Petersburg, Florida, USA.
[2]School of Marine and Atmospheric Science, Stony Brook University, Stony Brook, New York, USA.
[3]Marine Science Program & Department of Earth and Ocean Sciences, University of South Carolina, Columbia, USA.
[4]Estación de Investigaciones Marinas de Margarita, Fundación La Salle de Ciencias Naturales, Apartado 144, Porlamar, Estado Nueva Esparta, Venezuela.

Presenting author: emontesh@mail.usf.edu

## NUMERICAL SIMULATION OF NUTRIENT, PLANKTON AND DISSOLVED OXYGEN AND ITS RELATION WITH FISH MASS MORTALITY IN JAKARTA BAY, INDONESIA

[1]Susanna Nurdjaman, [2]Sam Wouthuyzen, [1]Ivonne M. Radjawame, dan [1]Sripardi Jamelina

Thousands of fish kill in Jakarta Bay some time ago into a kind of warning that it was time to monitoring and evaluation of the water quality conditions. Many suspected causes of mass mortality events of fish that are low levels of dissolved oxygen, blooming phytoplankton, heavy metals pollutants and others. Dissolved oxygen concentrations obtained by modeling the numerical simulation of three-dimensional ecosystem model of linking between the oxygen dissolved in nutrient levels, phytoplankton, zooplankton and detritus. From the model results obtained that the levels of dissolved oxygen concentration for all seasons spread evenly to all waters and has a relatively low value of between 3-4 ppm where the levels are optimal for life at sea is above 5 ppm. Based on satellite image data, before the mass death of fish, there was an blooming of phytoplankton and high sea surface temperatures, leading to low levels of dissolved oxygen. Therefore, based on the fact that it is strongly suspected that the low dissolved oxygen as the cause of mass mortality of fish in Jakarta Bay.

[1]Department of Oceanography, Faculty of Earth Sciences and Technology, Bandung Institute of Tehcnology, Indonesia
[2]Indonesia Research Center for Oceanography, Indonesia

Presenting author: susanna@fitb.itb.ac.id

## APPLICATION OF THE NESTED BIOLOGICAL-PHYSICAL MODEL TO THE EAST SEA

Yuri Oh and Chan Joo Jang

A three-dimensional model coupled with a four-component (NPZD) low trophic model is applied to the East Sea, focusing on ecosystem responses to upwelling environment near the Korean coast. The physical model is based on the Regional Ocean Model System (ROMS). The biological model was initialized with horizontally-uniform vertical profiles of N, P, Z and D. Reproduced chlorophyll features such as chlorophyll filaments and chlorophyll eddy are similar with ocean physical features of the East Sea, and agree well with Geostationary Ocean Color Image (GOCI) of Korea Ocean Satellite Center (KOSE). Our simulation shows that, during heating season, the coastal upwelling near the Korean coast largely controls ecosystem evolution and subsurface chlorophyll maximum (SCM) in this area is reproduced near the thermocline with appropriate spatial scales and tends to deepen toward the open ocean, compared with previous studies. During cooling the SCM disappears and chlorophyll is well mixed in the upper ocean.

Ocean Circulation and Climate Research Division, Korea Institute of Ocean Science & Technology, 787 Haean st., Sangnok-gu, Ansan, Gyeonggi, 426-744, South Korea.

Presenting author: ourmail@kiost.ac

## THE FATE OF RHONE RIVER CARBON ON THE MEDITERRANEAN CONTINENTAL MARGIN, ITS EXPORT TO THE OPEN SEA AND ITS RELATION TO CLIMATIC PARAMETERS

Rabouille C.[1], O. Radakovitch[2], C. Estournel[3], X. Durrieu de Madron[4], C. Guieu[5], R. Sempéré[6]

The MERMEX programme (Marine ecosystems response in the Mediterranean Experiment) seeks to understand the functioning of Mediterranean marine ecosystems and their response to human and climatic forcings. One of its 5 components deals with the “land-Ocean interactions including extreme events” and is focusing on the continental margin. Main interests concern the fate of river nutrients, carbon and contaminants on the continental shelf, the impact of large cities on the marine ecosystems, the fluxes of submarine groundwater discharge and how those inputs impact marine ecosystems.

In the first action by coupling long term observations and intensive surveys during key periods (such as flood events), we examine the transformations of Rhone River particles during their transfer from source to sink on the Gulf of Lions which is the largest river-dominated ocean margin of the Western Mediterranean Sea. In order to do that, MERMEX has set two observatories near the Rhone mouth and mid shelf and performed a series of surveys from the Rhone to the western canyons which play a key role in particulate export. Fixed station carry out continuous measurements using moored current meters and hydrological sensors, complemented by seasonal surveys during which most of the biogeochemical measurements are performed. In addition, process-oriented cruises were implemented to study event-triggered processes such as cascading in canyons.

We show that most biogeochemical transformations of river particles occur very close to the river mouth while transfer over long distances over the shelf affect only marginally sediment composition in the mid-shelf mud belt. Export occurs mostly in the western canyons as proposed in previous studies. Event driven processes are most important both during floods for the input and during stormy and cold winters for canyon export pointing out to a climatic regulation of input-output balance in the Gulf of Lion.

[1]LSCE, Gif sur Yvette, France
[2]CEREGE, Aix en provence, France
[3]POC, Laboratoire d’Aérologie, Toulouse, France
[4]CEFREM, Perpignan, France
[5]LOV, Villefranche, France
[6]MIO, Marseille, France

Presenting author: rabouill@lsce.ipsl.fr

## SI INPUTS TO THE WORLD OCEAN: NEW INSIGHTS FROM THE CONGO MARGIN AND DEEP SEA FAN

Ragueneau, O., Jacques, V., Corvaisier, R., Moriceau, B., Gallinari, M., and Raimonet, M.

Silicon (Si) inputs to continental margins and the open ocean play a major role in the control of coastal ecosystems and the oceanic carbon pump. During long, it was thought that Si delivery was mostly natural, from rivers. In the last three decades, the influence of Man on Si delivery has been demonstrated, mostly through eutrophication, river damming and the proliferation of invasive species. Here, we will suggest two important pathways for Si delivery to the deep ocean which clearly deserve more attention.

The first mechanism may be site-specific, related to the existence of the Congo canyon, which delivers biogenic matter some 800 km from the river mouth, in a deep-sea fan. A detailed study of Si accumulation in that area suggests that 50% of Si river inputs from the Congo accumulates there annually. Si:C ratios, very low (0.18) and only twice as high as that measured in the river itself, suggest that material is delivered directly through the canyon, with very little time for Si and C decoupling to take place.

The second mechanism, which may be of global importance, derives from the establishment of an Si mass balance on the Congo Margin; it shows an excess of Si accumulation and recycling at the rise of the continental slope, compared to pelagic sedimentation, which could only be explained by lateral inputs of amorphous silica, most probably from downslope transport. Global extrapolation suggests that this mechanism may be as important as river fluxes in delivering Si to the world ocean.

Olivier Ragueneau, UMR 6539, Institut Universitaire Européen de la Mer, Technopôle Brest-Iroise, 29280 Plouzané, France

Presenting author: Olivier.Ragueneau@univ-brest.fr

## DISSOLVED CARBON FLUXES FROM THE HOOGHLY ESTUARY, INDIA

Banerjee, K[1], Purvaja, R[2], and Ramesh, R[2]

Riverine input of dissolved and particulate carbon into the ocean is an important link in biogeochemical carbon cycling between land and ocean. This study reports the seasonal fluvial fluxes and estuarine transport of dissolved inorganic carbon [DIC] from the Hooghly estuary [Ganges] to the Bay of Bengal. Using the LOICZ Nutrient Budget Model, dissolved inorganic carbon fluxes were made for dry and wet seasons respectively, representing three boxes i) river, ii) estuary [system] and iii) ocean [Bay of Bengal]. The DIC budget varied distinctly between the dry [21.740 x 106 mol d-1] and wet [435.178 x 106 mol d-1] seasons, clearly suggesting the dominance of high fluvial discharge during the wet season. In both seasons, “system” served as a source of DIC possibly due to the generation of excess DIC due to mineralization of the riverine and/or in-situ produced organic carbon (OC) either in the form of dissolved organic carbon (DOC) or particulate organic carbon (POC).

The concentration of DOC followed the seasonal pattern as observed for DIC in this study, with higher net flux [17.438 x 106 mol d-1] in the wet and lower fluxes in the dry season [7.378 x 106 mol d-1]. The source of this increased DOC input to the ‘system’ [Hooghly estuary] during wet season is derived from the decomposition of litter in the adjacent Sundarban mangroves and from land based sources through the Hooghly River. The higher organic carbon from both these sources into the estuarine system causes a net heterotrophy in the system during both wet and dry periods. The results indicate that there is no net outflux of DIC and DOC into the ocean [Bay of Bengal] from the Hooghly estuarine system but is a net source of $CO_2$ to the atmosphere.

[1]Institute for Ocean Management, Anna University, Chennai 600 025, India
[2]National Centre for Sustainable Coastal Management, Ministry of Environment and Forests, Anna University Campus, Chennai 600 025, India

Presenting author: rramesh_au@yahoo.com

**ATMOSPHERIC DEPOSITION OF N, P AND Fe TO THE NORTHERN INDIAN OCEAN: IMPLICATIONS TO SURFACE OCEAN BIOGEOCHEMISTRY**

M. M. Sarin and Bikkina Srinivas

We present a first comprehensive data-set on the atmospheric dry-deposition of N, P and Fe to the Bay of Bengal (BoB) and the Arabian Sea (ARS). The chemical composition of ambient aerosols, studied from marine atmospheric boundary layer during the continental outflow (January-April), exhibit pronounced spatio-temporal variability. The dry-deposition fluxes are relatively high over the BoB [$N_{Tot}$: 2 – 167 µmol $m^{-2}$ $d^{-1}$, $P_{Inorg}$: 0.5 – 4.8 µmol $m^{-2}$ $d^{-1}$ and $Fe_{ws}$: 0.02 - 1.2 µmol $m^{-2}$ $d^{-1}$, where $N_{Tot}$ is ($N_{Inorg}$ + $N_{Org}$) and $Fe_{ws}$ refers to water-soluble fraction of aerosol-Fe]. In contrast, air-sea deposition fluxes to the ARS are ($N_{Tot}$: 0.2 – 18.6 µmol $m^{-2}$ $d^{-1}$, $P_{Inorg}$: 0.3 - 0.9 µmol $m^{-2}$ $d^{-1}$ and $Fe_{ws}$: 0.7 - 15.3 nmol $m^{-2}$ $d^{-1}$). The atmospheric deposition of N and P is of comparable magnitude to their supply via rivers in the two oceanic regions, suggesting dominant contribution from anthropogenic sources. Assuming Redfield stoichiometry and complete utilization of $N_{Tot}$ by phytoplankton, atmospheric input can account for ~13 and 1% of the Primary Production in BoB and ARS, respectively. Using atmospherically derived P- and Fe-fluxes, C-fixation in the BoB (1.1 Pg $yr^{-1}$) is considerably higher than that in ARS (0.03 Pg yr-$^{1}$). However, N-fixation in the two ocean basins is somewhat similar (~ 0.5 Tg $yr^{-1}$) and of comparable magnitude with other oceanic regions. With rapidly growing anthropogenic activities in south and south-east Asia, further increase in air-sea deposition flux of nutrients have potential to alter C-fixation in the Northern Indian Ocean.

Physical Research Laboratory, Ahmedabad-38009, India

Presenting author: sarin@prl.res.in

## MASSIVE NITROGEN LOSS IN THE SEASONAL OXYGEN-DEFICIENT ZONE OVER THE WESTERN INDIAN CONTINENTAL SHELF

Amit Sarkar[1], Wajih Naqvi[1], Anil Pratihary[1,2], Hema Naik[1], Gayatree Narvenkar[1], Damodar Shenoy[1], Mangesh Gauns[1], Gaute Lavik[2], Marcel Kuypers[2]

The world's largest natural coastal hypoxic zone develops over the western Indian continental shelf during late summer/early autumn. Besides experiencing sulphidic conditions on a regular basis, which is believed to manifest a human-induced intensification in the recent past, a distinguishing feature of this system is the record-high buildup of nitrous oxide. Time-series chemical data and coast-perpendicular sections indicate rapid loss of fixed N, but the processes responsible for N loss are not fully understood. We measured N loss rates directly through shipboard incubation of water samples spiked with $^{15}N$-labeled substrates (nitrate, nitrite and ammonium) along several coast-perpendicular transects of the shelf during the periods of suboxia/anoxia for four consecutive years (2008 to 2011). Denitrification was found to be the dominant pathway of $N_2$ production, especially in inner-shelf waters that were close to being sulphidic. In contrast, anaerobic ammonium oxidation (anammox) rates were close to the detection limit. Dissimilatory nitrate reduction to ammonia (DNRA), measured on a few occasions, was also not detected in any sample. The N loss rates measured by us are the highest ever found in non-sulphidic waters and are much higher than the rates reported previously from coastal Arabian Sea. Significant inter-annual variability in the N loss rate was observed. The confinement of very high rates to the inner shelf in proximity to sulphidic/near-sulphidic zones and the rapid offshore attenuation suggest sulphide-driven chemolitho-autotrophic denitrification as the principal mode of N loss.

[1]National Institute of Oceanography, Dona Paula, Goa 403 004, India
[2]Max-Planck Institute for Marine Microbiology, Celsiusstrasse 1, Bremen 28359, Germany

Presenting author: amit.sarkar@nio.org

## COASTAL EASTERN ARABIAN SEA – A HOTSPOT FOR PRODUCTION OF NITROUS OXIDE, METHANE AND DIMETHYL SULPHIDE

Damodar Shenoy[1], Hema Naik[1], Mangesh Gauns[1], Siby Kurian[1], Anil Pratihary[1, 2], Gayatri Narvenkar[1] and SWA Naqvi[1]

One of the most concerning aspect of the ongoing global change is the emergence and expansion/intensification of low oxygen zones in marine environments that may enhance oceanic emissions of greenhouse gases such as nitrous oxide ($N_2O$) and methane ($CH_4$). Like carbon dioxide, these gases also provide a positive feedback to global warming; by contrast, dimethyl sulphide (DMS) has a negative feedback. The coastal eastern Arabian Sea provides suitable conditions for vigorous production/consumption of these gases, as revealed by the data collected at a quasi time series station, the Candolim Time Series (CaTS), located off Goa. Seasonal upwelling in conjunction with freshwater runoff creates a mosaic of redox conditions ranging from fully oxic to fully anoxic (sulphidic) over the western Indian shelf. The most interesting feature is the large build-up of $N_2O$ (to ~0.8 µM) in waters that are just short of being sulphidic. Modest accumulation of $CH_4$ (to ~50 nM) and DMS (to ~0.4 µM) is observed in sulphidic parts. Interestingly, total dimethylsulphoniopropionate, DMS and methanethiol could not account for the high DMS concentration. While peak $N_2O$ concentration is the highest observed in the open ocean, the maximal concentration of $CH_4$ is substantially lower than that reported from other sulphidic systems (e.g. off Namibia) presumably due to differences in hydrography and primary productivity.

[1]National Institute of Oceanography, Dona Paula, Goa 403 004, India

[2]Max Planck Institute for Marine Microbiology, Celsiusstrasse 1, D-28359 Bremen, Germany

Presenting author: dmshenoy@nio.org

## NET ANTHROPOGENIC NUTRIENT INPUTS AND NUTRIENT FLUXES FROM WATERSHEDS

Dennis P Swaney, Bongghi Hong, Robert W Howarth, Ramesh Ramachandran

Simple budget and accounting procedures were among the earliest quantitative methods applied to coastal waters and their watersheds for assessing the magnitudes of material fluxes. More recently, the Land Ocean Interactions in the Coastal Zone (LOICZ) program first attempted to outline a methodology to assess biogeochemical budgets of coastal water bodies and their implications for coastal ecosystem metabolism in the early 1990s. An original goal of LOICZ was to evaluate its global significance and regional variation, especially along the coastlines of developing countries. Beginning around the same time, and working independently, researchers in the SCOPE Nitrogen project began to construct simple accounting approaches for relating nutrient inputs to coastal watersheds to nutrient export to the coast. A primary aim was to demonstrate the relative importance of anthropogenic nutrient inputs to watersheds on the load to coastal waters. While the aims and development of the approaches were different, they exhibit some basic similarities. Here, we summarize the net anthropogenic nitrogen input (NANI) methodology, show recent examples of analyses which demonstrate how the NANI framework for assessing nitrogen fluxes resulting from human activity relates to nutrient loads to coastal ecosystems, and discuss its potential application to Indian watersheds.

Cornell University, Ecology & Evolutionary Biology, E309 Corson Hall, Tower Rd, Cornell University, 14853, Ithaca, New York, USA

Presenting author: dps1@cornell.edu

## SHELVES OF THE ARCTIC OCEAN: C FLUX AND CLIMATE CHANGE

Paul Wassmann[1], Dag Slagstad[2] and Ingrid Ellingsen[2]

Primary and secondary production on the Eurasian shelves and the Barents Sea were investigated through the physically-biologically coupled, 3D SINMOD model. We tested the effect of how retreating ice cover in the forthcoming century may affect the productivity in the Arctic Ocean by forcing the model with two IPPC climate scenarios (B1 and A2). The model predicts strongly decreasing ice extent during the 21st century. Transition to ice-free areas is abrupt and is accompanied with large interannual variability. Changes in ice conditions suggest a great impact on the physical environment of the Arctic Ocean by altering water mass composition. There is a great variability in primary production in the present seasonal ice zone. There will also be changes in the geographical position of seasonal ice zone and less variability in areas that no longer has a seasonal ice cover. The model predicts that annual primary production decreases in areas dominated by Atlantic Water. This change is mainly driven by decrease of nutrient content of inflowing Atlantic Water and by reduced winter mixing caused by increased thermal stratification.

The model indicates that Gross Primary production (GPP) increases along the temperature gradient both in the Arctic Basin and along the Eurasian shelves from 10 to 40 and 30 to 60 g C $m^{-2}$ $y^{-1}$, respectively. In contrast, GPP in the Barents Sea stayed more or less constant (100 g C $m^{-2}$ $y^{-1}$). With an air temperature increase towards +8°C secondary production of *Calanus glacialis* in the Barents Sea dropped from about 3.9 to 0.3 g C $m^{-2}$ $y^{-1}$, while that of the Arctic Basin and Eurasian shelf increased from approximately -0.1 to 1.5 and 1.4 to 2.4 g C $m^{-2}$ $y^{-1}$, respectively. Secondary production changes are unevenly distributed during future warming with the most significant increases occurring along the Eurasian shelves and the Chukchi Sea.

[1]Institute of Arctic and Marine Biology, Faculty for Biosciences, Fisheries and Economy, University of Tromsø, N-9037 Tromsø, Norway
[2]SINTEF Fisheries and Aquaculture, 7465 Trondheim, Norway

Presenting author: paulw@nfh.uit.no

## OXYGEN MINIMUM ZONES, ZOOPLANKTON LAYERS, AND GLOBAL CHANGE

Karen Wishner

Oceanic oxygen minimum zones (OMZs), characteristic continental margin features of eastern oceanic ecosystems and the Arabian Sea, may be expanding in their spatial and vertical extent as a result of global warming. The extremely low oxygen concentration in these habitats strongly affects the structure and function of zooplankton communities, leading to the occurrence of distinct zooplankton layers at the upper and lower OMZ boundaries (upper and lower oxyclines) and life history strategies of some zooplankton species that utilize these gradients. These layers are likely of key important for coastal fisheries since the concentrated zooplankton provide an accessible food source for fish. In addition, the vertical positioning of focused layers influences zooplankton feeding and particle re-packaging activity, presumably affecting vertical fluxes and benthic-pelagic coupling. In the Eastern Tropical Pacific, a spatial comparison between 2 locations with different OMZ thicknesses provided a proxy for future climate change effects. The thermocline was the location of peak zooplankton biomass, associated with both temperature and oxygen gradients. At the lower oxycline, a unique zooplankton community was apparently locked in position by oxygen concentration and changed depth by over 200 m between locations despite a temperature difference. However, the depth of daytime diel vertical migration into the OMZ remained relatively constant despite changes in oxygen between locations and the amount of low oxygen water through which the migrators transited. Consequences for coastal fisheries and communities of future environmental changes are being explored, especially the possibility of regime shifts beyond the adaptive capacity of the present fauna.

University of Rhode Island, Narragansett, RI, USA

Presenting author: kwishner@gso.uri.edu

## THE RESPONSE OF A GULF ESTUARY HYPOXIA TO WIND FORCING

Meng Xia, Long Jiang, Qianru Niu

Perdido Bay Estuary (PBE), a typical bay on the Florida/Alabama coast along the Gulf, was simulated using an existing calibrated model (Xia et al., 2011). Hindcasts of Perdido Bay bottom hypoxia is provided in response to local wind forcing. Observed average wind speeds of 3 m $sec^{-1}$ during July were capable of redistributing hypoxia stressing the entire estuarine ecosystem. Easterly and westerly winds resulted in greater hypoxia near the shore, which put stress on near-shore habitats such as oysters and result in phenomenon like jubilees. Westerly and southerly winds resulted in significantly larger areas of anoxic conditions due to longer water-residence times that allowed continued surface primary production and subsurface microbial decomposition. Northerly and easterly winds, in contrast, promoted water transport toward the Gulf of Mexico, enhancing the freshwater discharge direction from Perdido River. Wind speeds over 3 m $sec^{-1}$ were sufficient to enhance the advection of dissolved oxygen into bottom waters through vertical mixing and resulted in significant reductions in areal coverage of hypoxia. Therefore, periodic summer storms may alleviate hypoxic conditions within the estuary.

Department of Natural Sciences, University of Maryland Eastern Shore, Princess Anne, MD, 21853, USA

Presenting author: mxia@umes.edu

# Workshop 2: The impact of anthropogenic perturbations on open ocean carbon sequestration via the dissolved and particulate phases of the biological carbon pump

**Chair: Helmuth Thomas**

This workshop will attract scientists from multiple disciplines including microbial ecologists, biogeochemists, organic chemists, climate scientists, fisheries scientists and economists to exchange ideas and devise strategies to integrate the MCP into the concepts and models of carbon sequestration in the ocean's and the global carbon cycle. The recognition of the significance of MCP-based carbon sequestration and its interaction with the BP will deepen our current knowledge for predicting the outcomes of geo-engineering of the ocean carbon cycle (e.g. by iron fertilization etc.). Of considerable interest is the possibility that the integration of MCP processes to better understand the ocean carbon cycle may lead to win-win strategies for enhanced carbon sequestration. IMBIZO is an excellent opportunity to discuss future natural and social science research needs to integrate the MCP to better understand the marine carbon cycle, as well as multi-disciplinary brainstorming on "eco-engineering" as system-based optimization of multiple desirable environmental goals.

Anthropogenic impacts such as elevated $pCO_2$ and eutrophication threaten the structure and functioning of marine ecosystem as well as the role of the ocean in the global carbon cycle. The ocean absorbs approximately one-third of the $CO_2$ released by fossil fuel combustion (Doney et al., 2004) raising the question of the potential of the ocean for long-term net carbon sequestration. While sinking-particle-based carbon sequestration (the biological pump; BP) has been extensively studied, the biogeochemical behaviour of dissolved organic matter (DOM) - and its potential role in climatically significant carbon sequestration in the dissolved phase (the microbial carbon pump, MCP; Jiao et al., 2010) is largely unexplored. Furthermore, while the impacts of changes in thermal stratification on the BP have been discussed at an earlier IMBIZO workshop, the effects of climate change and anthropogenic perturbations such as eutrophication and ocean acidification on the MCP and BP remain poorly understood.

The BP and the MCP operate simultaneously and interactively but their responses to environmental conditions may be regulated differently (e.g. in shallow coastal waters versus deep waters; oligotrophic oceanic waters versus eutrophic waters) but these regulatory mechanisms have not been examined - particularly for MCP-based carbon sequestration. Further, it is not known whether the BP and the MCP would interact to enhance or reduce their individual effects. A potential effect of eutrophication, or

nutrient addition in general, (in addition to algal blooms and hypoxia) may be a shift in the balance of carbon sequestration via the MCP and the BP. Predictions of any marine carbon cycle manipulations should therefore take into account such potential interactions between the BP and the MCP. For example, it is possible that reducing the use of chemical fertilization on the land could lead to an enhancement of the MCP as a carbon sink in eutrophic coastal waters (Jiao et al., 2010). Fishing practices are further changing the structure of the marine food web and the dominant pathways of carbon flow in marine ecosystems, so an integrative consideration of the BP and the MCP could help identify practices conducive to enhanced carbon sequestration. Such comprehensive ecosystem based optimizations (rather than piecemeal manipulations) of the regulation of the ocean carbon cycle may benefit from emerging knowledge of previously unrecognized carbon sinks, notably the MCP.

Processes, which are deemed to interfere with the MCP and BP and their interaction, in the open oceans, and which may be considered for discussion during the workshop comprise (non-exclusively) nutrient addition from land via rivers and the atmosphere, intentional and unintentional addition of trace elements, and ocean acidification, as well as comparisons with environments having naturally accentuated occurrences of anthropogenic species affecting the BP and the MCP.

**Workshop conveners:**

- Farooq Azam (Scripps Institute for Oceanography, USA)
- Nianzhi Jiao (Xiamen University, China)
- Carol Robinson (University of East Anglia, UK)
- Helmuth Thomas (Dalhousie University, Canada)

**Plenary speakers:**

- Farooq Azam (Scripps Institute for Oceanography, USA)

## Workshop 2
## Impacts of anthropogenic perturbations on the BP and MCP in the open ocean

| **DAY 1 - Monday 28 January** | |
|---|---|
| 08:00-09:00 | IMBIZO lll Registration |
| 09:00-09:15 | Welcome – **Eileen Hofmann, Alida Bundy and Kon-Kee Liu** |
| 09:15-10:00 | Workshop 1 Keynote presentation: Ocean hypoxia from physics to fish – **Curtis Deutsch** |
| 10:00-10:45 | Workshop 1 Keynote presentation: Nutrients, hypoxia and fisheries: lessons about multiple stressors from the Chesapeake and beyond – **Denise Breitburg** |
| 10:45-11:15 | *Coffee break* |
| 11:15-12:00 | Workshop 2 Keynote presentation: Microbial carbon pump and ecosystem connectivity – **Farooq Azam** |
| 12:00-12:45 | Workshop 3 Keynote presentation: "ADApT or Die": Finding methodologies to secure the livelihoods and food security for fisheries dependent communities around the world – **Moeniba Isaacs** |
| 12:45-13:45 | *Lunch* |
| 13:45-14:20 | Workshop 2 overview and objectives – processing of DOC, interactions between MCP and BP, perturbations and links to humanity and large scale C cycling – **Farooq Azam, Nianzhi Jiao, Carol Robinson and Helmuth Thomas** |
| 14:20-15:30 | **Session 1.a - Chair: Farooq Azam**<br>**Nature of DOC** |
| 14:20-14:50 | Ageing of marine dissolved organic matter: A molecular perspective - **Boris Koch** |
| 14:50-15:10 | Probing the microbial carbon pump in proterozoic oceans - **Chao Li** |
| 15:10-15:30 | Production of exopolysaccharide by marine bacteria - **Zilian Zhang** |
| 15:30-16:00 | *Coffee break* |
| 16:00-17:00 | **Session 1.b - Chair: Carol Robinson**<br>**Microbial processing of DOC and genetic diversity** |
| 16:00-16:20 | Prokaryotic autotrophy in the meso- and bathypelagic Atlantic Ocean - **Gerhard Herndl** |
| 16:20-16:40 | Deep-sea prokaryotic heterotrophic activity in the world's oceans – **Thomas Reinthaler** |
| 16:40-17:00 | Understanding controls of diel patterns of biological $CO_2$ fixation in the North Atlantic Ocean - **Helmuth Thomas** |
| 17:00-18:00 | **Plenary session discussion – Chair KK Liu, Rapporteur: Karen Wishner**<br>How do biogeochemistry and ecosystems interact in response to natural or man-induced forcing in continental margins and how can such knowledge forge better management of the marine realm? |
| 18:00-19:30 | *Ice breaker and poster session* |

| DAY 2 - Tuesday 29 January | |
|---|---|
| 09:00-10:30 | **Session 1.c – Chair: Gerhard Herndl**<br>**Microbial processing of DOC and genetic diversity** |
| 09:00-09:10 | Recap of sessions 1a and 1b and the session 1 objectives – **Farooq Azam** |
| 09:10-09:30 | MCP, Microbial respiration and ecological efficiency in estuarine ecosystems - **Hongyue Dang** |
| 09:30-09:50 | The meaning of diversity for understanding the microbial carbon pump in the oceans - **David Kirchman** |
| 09:50-10:10 | Distribution and function of genes related to microbial dissolved organic matter utilization - **Kai Tang** |
| 10:10-10:30 | Diversity of nasA genes in the global oceans - **Xuexia Jiang** |
| 10:30-11:00 | *Coffee break* |
| 11:00-12:30 | **Synthesis 1 - Chair: Carol Robinson**<br>**Microbial processing of DOC** |
| 12:30-13:30 | *Lunch* |
| 13:30-15:00 | **Session 2.a - Chair: Nianzhi Jiao**<br>**Interactions between MCP and BP** |
| 13:30-13:50 | Potential effects of ocean warming on the biological and microbial carbon pumps - **Louis Legendre** |
| 13:50-14:10 | Autotrophic and heterotrophic responses to iron and nutrient enrichment in the western Pacific Ocean - **Qian Li** |
| 14:10-14:30 | Microbial loop and carbon export in the subtropical ocean **– Susanne Neuer** |
| 14:30-15:00 | The ecological effects of marine microbial aggregates on DOC and POC **- Xiaoxue Wang** |
| 15:00-15:30 | *Coffee break* |
| 15:30-17:00 | **Session 2.b - Chair: Victor Smetacek**<br>**Interactions between MCP and BP** |
| 15:30-15:50 | The rise and dominance of mixotrophic protists in a changing world; redefining the functionality of the biological and microbial carbon pumps - **Aditee Mitra** |
| 15:50-16:10 | Sensitivity of the ocean biological pump to parameterizations of the recycling matter - **Anastasia Romanou** |
| 16:10-16:30 | Carbon export algorithm advancement in models - **Çağlar Yumruktepe** |
| 16:30-17:00 | Discussion – **Chair: Carol Robinson** |
| 17:00-18:00 | **Plenary session discussion – Chair: Helmuth Thomas**<br>How may current understanding of deep ocean processes translate to better assessment and stewardship of fundamental ecological services that deep oceans provide? |
| 18:00-20:00 | Poster session & BBQ |

| DAY 3 - Wednesday 30 January | |
|---|---|
| 09:00-10:30 | **Session 2.c - Chair: Farooq Azam**<br>**Response to anthropogenic perturbation** |
| 09:00-09:10 | Recap sessions 2a and 2b and the Session 2 objectives (**Chair: Nianzhi Jiao**) |
| 09:10-09:30 | Responses of the "Biological pump" and the "Microbial carbon pump" to nutrient perturbations in natural and anthropogenic scenarios **- Nianzhi Jiao** |
| 09:30-09:50 | Possible changes in the dynamics of particulate carbon sequestration in the open ocean associated to anthropogenic perturbations of the environment - **Juan Carlos Miquel** |
| 09:50-10:10 | Microbiological and photochemical transformation of organic carbon during an in situ iron and phosphate addition experiment - **Carol Robinson** |
| 10:10-10:30 | The effect of nitrogen and phosphorus on CDOM generated by bacteria - **Rui Ren** |
| 10:30-11:00 | *Coffee break* |
| 11:00-12:00 | **Session 2.d – Chair: David Kirchman: Response to anthropogenic perturbation** |
| 11:00-11:20 | On exploiting the potential of ocean iron fertilization experiments for testing hypotheses on the carbon pump and ecosystem restoration **- Victor Smetacek** |
| 11:20-11:40 | Response of bacterioplankton community structure to an artificial gradient of $pCO_2$ in the Arctic Ocean - **Rui Zhang** |
| 11:40-12:00 | Will ocean acidification or eutrophication impact bacterioplankton diversity and carbon processing in the coastal Mediterranean Sea **- Federico Baltar** |
| 12:00-12:30 | **Discussion** |
| 12:30-13:30 | *Lunch* |
| 13:30-17:00 | **Session 3.a – Chair: Helmuth Thomas**<br>**Large temporal and spatial scale dynamics and links to humanity** |
| 13:30-13:50 | The global alliance of continuous plankton recorder surveys (GACS): a tool for multi-decadal monitoring the ocean's response to human and other global change processes - **Peter Burkill** |
| 13:50-14:10 | Role of meso-scale eddies on the variability of biogenic flux in the northern and central Bay of Bengal – **P.J. Vidya** |
| 14:10-14:30 | Effects of anticyclonic eddy from the Kuroshio on the winter phytoplankton bloom in the South China Sea: An eddy-resolving physical-biological model study **- Yoshikazu Sasai** |
| 14:30-14:50 | The influence of the Indian Ocean dipole on interannual variations in phytoplankton size structure as revealed by earth observation - **Nick Hardman-Mountford** |
| 15:00-15:30 | *Coffee break* |
| 15:30-15:50 | Studying oxygen minimum zones in the Northern Indian Ocean using Argo-Oxygen data - **Satya Prakash** |
| 15:50-17:00 | **Synthesis 2 - Chair: Nianzhi Jiao**<br>**MCP - BP interactions: Response to perturbations and large scale dynamics** |
| 17:00-18:00 | **Plenary session discussion – Chair: Alida Bundy**<br>How can natural and social scientists optimize their cooperation to achieve usable and integrated knowledge and understanding to support policy making and form viable feedback loops between the natural system and human society? |
| 19:15-22:30 | *IMBIZO lll dinner – Hawaii Beach Restaurant* |

## Workshop 2: OPEN OCEAN

| DAY 4 - Thursday 31 January | |
|---|---|
| 09:00-12:30 | **Session 4: Workshop 2 synthesis - Chairs: Helmuth Thomas, Carol Robinson, Nianzhi Jiao, Farooq Azam**<br>**Processing of DOC, interactions between MCP and BP, perturbations and links to humanity and large scale C cycling** |
| 09:00-10:30 | **Synthesis - Chairs: Carol Robinson, Nianzhi Jiao**<br>**Workshop 2 objectives and special issue** |
| 10:30-11:00 | *Coffee break* |
| 11:00-12:30 | **Synthesis continued** |
| 12:30-13:30 | *Lunch* |
| 13:30-15:00 | Final plenary session<br>Summary reports from Workshops 1, 2 and 3 and plenary discussion sessions |
| 15:00 | Closing comments, end of meeting |

**Legend:**

| |
|---|
| IMBIZO joint sessions |
| Workshop session themes |
| Joint social activities |
| Discussion sessions |

## MECHANISMS REGULATING MICROBIAL SEQUESTRATION AND MOBILIZATION OF CARBON IN THE OCEAN: FROM MOLECULAR INTERACTIONS TO ECOSYSTEM CONNECTIVITY

Farooq Azam and Francesca Malfatti

Our understanding of carbon sequestration mechanisms in the ocean has been extensively studied in the context of the biogeochemical behavior of the particulate phase—particularly the biological regulation of downward flux of carbon. Some studies have also considered the microbes' role in the transformation of particles to the dissolved organic matter. The Microbial Carbon Pump is a mechanism for dissolved phase carbon sequestration, operating in concert with the particulate phase biological carbon pump. The challenge is to mechanistically assimilate the immense microbial diversity and biochemical expressions in an ecosystem context—and how they shape the emergent biogeochemical state of ocean ecosystems. Further, organic matter occurs as a chemically diverse size-continuum from monomers to large particle. Microbes interact with all ecosystem facets. *We propose that the complex and highly abundant communities of microbes are a major and critical structuring force for ecosystem connectivity and resilience* through their cumulatively diverse metabolic interactions with the organic matter continuum –including all biotic and abiotic components. This molecular-level integrative view of ocean ecosystems can help develop new mechanistic models of biogeochemical variability and resilience and ecosystem response to climate change.

Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093, USA

Presenting author: fazam@ucsd.edu

## WILL OCEAN ACIDIFICATION OR EUTROPHICATION IMPACT BACTERIOPLANKTON DIVERSITY AND CARBON PROCESSING IN THE COASTAL MEDITERRANEAN SEA?

Federico Baltar[1*], Joakim Palovaara[1], María Vila-Costa[2], Hugo Sarmento[3], Eva Calvo[3], Cèlia Marrasé[3], Josep M Gasol[3], Jarone Pinhassi[1]

Anthropogenic impacts such as ocean acidification and eutrophication menace the structure and functioning of marine ecosystem and the consequential role of the ocean in the global carbon cycle. Despite marine prokaryotes play a paramount role in marine carbon fluxes, it is not clear if their diversity and functioning will be affected by changes in pH or/and nutrient concentration. We studied the response of bacterioplankton to reduced pH (ca. 0.3 units lower than the pH in the control mesocosm) and inorganic nutrient additions (ca. 10x the N and Si concentrations found commonly in situ, and P added at Redfield ratios) in three mesocosm experiments with water collected from the Bay of Blanes (NW Mediterranean Sea), two in winter and one in summer conditions. We tracked the daily changes in prokaryotic abundance and heterotrophic production (leucine incorporation), together with the analysis of the prokaryotic community composition (454 tag pyrosequencing of 16S rRNA) at the beginning and at the end of our 8 days experiments. Acidification did not alter prokaryotic abundance, production or community composition. In contrast, nutrient enrichments increased prokaryotic cell numbers and production rates, particularly towards the end of the experiments. Nutrient additions changed the prokaryotic community structure, where some Flavobacteriaceae (*Polaribacter* and *Tenacibaculum)* and Rhodobacteraceae (*Roseobacter* and *Nereida*) were favored independently of pH changes. Thus, the coastal NW Mediterranean bacterioplankton community structure, and their mediated organic carbon production, should not be strongly affected by the predicted pH reduction, but are however very much susceptible to changes in inorganic nutrient loading.

[1]Centre for Ecology Evolution and in Microbial Model Systems, EEMiS, Linnaeus University, Barlastgatan 11, SE-391 82 Kalmar, Sweden
[2]Group of Limnology, Department of Continental Ecology, Centre d'Estudis Avançats de Blanes-CSIC, Accés Cala Sant Francesc, 14. 17300 Blanes, Catalonia, Spain
[3]Departament de Biologia Marina i Oceanografia, Institut de Ciències del Mar – CSIC, Pg. Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain

Presenting author: federico.baltar@lnu.se

## THE GLOBAL ALLIANCE OF CONTINUOUS PLANKTON RECORDER SURVEYS (GACS): A TOOL FOR MULTI-DECADAL MONITORING THE OCEAN'S RESPONSE TO HUMAN AND OTHER GLOBAL CHANGE PROCESSES

Peter Burkill[0], Graham Hosie[1], Sonia Batten[2], Sanae Chiba[3], Martin Edwards[2], Mitsuo Fukuchi[4], Julie Hall[5], Chris Melrose[6], Erik Muxagata[7], Nick Owens[2], Anthony Richardson[8], Sun Song[9], Hans Verheye[10],

Continuous Plankton Recorders have been deployed as a lower trophic level sampling tool for many decades in the North Atlantic, and have provided a wealth of data used to describe plankton diversity, biogeography, response to climate forcing and influence on upper trophic levels. Other regions of the ocean have since been monitored with CPRs; the Southern Ocean for over 20 years, the north Pacific for over 10 and new surveys have recently been initiated around Australia, New Zealand, Brazil and in the Benguela Current. The CPR has remained the instrument of choice because it offers a cost effective way to routinely sample deep ocean basins and coastal ecosystems seamlessly, and is the only current instrument that does so while measuring biodiversity of both zooplankton and larger phytoplankton. Recognising the need to combine expertise and data to address global issues affecting lower trophic levels (ocean warming, acidification etc.) a Global Alliance of CPR Surveys (GACS) was formed in September 2011. GACS will provide that global perspective using CPR data. It will also allow us to assess changes and events at a local or regional level in a world-wide context. The group has a board of governance comprising members from 9 regional CPR surveys and active working groups to develop a joint database and maintain working standards and methodologies. Other specific aims are to produce a regular ecological status report for global plankton biodiversity, and to provide an interface for plankton biodiversity with other global ocean observation programmes.

[0]University of Plymouth, UK
[1]Australian Antarctic Division, 203 Channel Highway, Kingston, Tasmania 7050
[2]Sir Alister Hardy Foundation for Ocean Science, Plymouth UK
[3]Japan Agency for Marine-Earth Science and Technology, Yokosuka Japan
[4]National Institute of Polar Research, Tokyo Japan
[5]National Institute for Water and Atmospheric Research, Wellington New Zealand
[6]National Oceanic and Atmospheric Administration, Narragansett USA
[7]Universidade Federal do Rio Grande, Brasil
[8]CSIRO, Brisbane
[9]Institute of Oceanology, Chinese Academy of Sciences, China
[10]Department of Environmental Affairs, Cape Town South Africa

Presenting author: peter.burkill@plymouth.ac.uk

## DATA MANAGEMENT IN SUPPORT OF IMBER RESEARCH

Cynthia L. Chandler

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) program involve multi-disciplinary topics and are therefore likely to require integration of data from disparate sources. Such integration can only be done if one has access to sufficient metadata (supporting documentation) to enable accurate interpretation of disparate data resources and re-use of 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. 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) providing data access systems that support data discovery, access, display, assessment, integration, and export of data resources; (5) submission of 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

Biological and Chemical Oceanography Data Management Office, Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA

Presenting author: cchandler@whoi.edu

## MCP, MICROBIAL RESPIRATION AND ECOLOGICAL EFFICIENCY IN ESTUARINE ECOSYSTEMS

Hongyue Dang[1,2], Nianzhi Jiao[1]

Although respiration consumes fixed carbon to produce $CO_2$, it also provides energy for the essential ecological processes of an ecosystem, including the operation of the Microbial Carbon Pump (MCP). In MCP-driving biotransformation of LDOC to RDOC, microbial respiration provides ATP, the direct energy, for cellular key enzyme syntheses and essential catalytic processes such as translocation, modification, fixation and storage of carbon compounds. The MCP efficiency of a heterotrophic microorganism may depend on its energy production efficiency, and thus on its respiration efficiency. Microorganisms carrying out aerobic respiration have higher energy production efficiency than microorganisms carrying out anaerobic respiration. Thus, an ecosystem that mainly carries out aerobic respiration may have higher MCP ecological efficiency than an ecosystem that carries out anaerobic respiration. Due to strong terrestrial input of nutrients and organic matter, an estuarine ecosystem usually experiences intense heterotrophic respiration processes that rapidly consume dissolved oxygen in seawater and sediments, producing extensive hypoxic and anoxic zones in the water column. The lowered availability of dissolved oxygen and the increased load of nutrients such as nitrate from river input prompt enhanced anaerobic respiration processes. Thus, most of the nutrients may be consumed by anaerobically respiring heterotrophic microorganisms, instead of being utilized by phytoplanktons for carbon fixation and primary production. In this situation, the ecological function of the estuarine ecosystem is altered and the ecological efficiency is also lowered, as less energy is produced. This may also negatively influence the ecological functionality and efficiency of MCP due to the lowered energy production efficiency.

[1]State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen 361005, China; [2]Centre for Bioengineering and Biotechnology, China University of Petroleum (East China), Qingdao 266580, China

Presenting author: DangHY20042000@yahoo.com.cn

## THE INFLUENCE OF THE INDIAN OCEAN DIPOLE ON INTERANNUAL VARIATIONS IN PHYTOPLANKTON SIZE STRUCTURE AS REVEALED BY EARTH OBSERVATION.

Robert J.W. Brewin [1,2], Takafumi Hirata [3], Nick J. Hardman-Mountford [4], Samantha J. Lavender [5], Shubha Sathyendranath [1,2], Ray Barlow [6,7]

We examine the implications of the Indian Ocean Dipole (IOD) for phytoplankton size structure, using a decade of satellite ocean-colour observations and a model that links chlorophyll-a to the size of the phytoplankton cells, parameterised using pigment data from the Indian Ocean. Interannual anomalies in phytoplankton size structure are related to those in sea-surface temperature (SST) and sea-surface height (SSH) and stratification. In regions influenced by the Indian Ocean Dipole, we observe a tight correlation between phytoplankton size structure and these physical variables, such that interannual variations in the physical variables accounts for up to 70% of the total variance in phytoplankton size structure. For much of the Indian Ocean, low temperature, low SSH and low stratification (indicative of a turbulent environment) are correlated with larger size classes, consistent with theories on coupling between physical–chemical processes and ecosystem structure. To the extent that phytoplankton function is related to its size structure, changes in physical forcing are likely to influence biogeochemical cycles in the region and the pelagic foodweb. We discuss the implications of these results in relation to potential climatic modification of the marine environment.

[1]Plymouth Marine Laboratory (PML), Prospect Place, The Hoe, Plymouth PL1 3DH, UK
[2]National Centre for Earth Observation, PML, Plymouth PL1 3DH, UK
[3]Graduate School of Environmental Science, Hokkaido University, North 10 West 5, Kita-ku, Sapparo, Hokkaido 060-0810, Japan
[4]CSIRO Marine and Atmospheric Research, Private Bag 5, Wembley WA 6014, Australia
[5]ARGANS Ltd, Unit3, Drake Building, Tamar Science Park, Derriford, Plymouth PL6 8BY, UK
[6]Bayworld Centre for Research & Education, P.O. Box 7296, Roggebaai 8012, South Africa
[7]Marine Research Institute, University of Cape Town, Private Bag X3, Rondebosch 7701, South Africa

Presenting author: nick.hardman-mountford@csiro.au

## PROKARYOTIC AUTOTROPHY IN THE MESO- AND BATHYPELAGIC ATLANTIC OCEAN

Gerhard J. Herndl, Roberta L. Hansman, Thomas Reinthaler

Chemoautotrophy in the meso- and bathypelagic ocean has recently been identified as a significant metabolic pathway of prokaryotes comparable to the magnitude of heterotrophic prokaryotic metabolism. While some studies have implicated the oxidation of ammonia by members of Thaumarchaeota as fueling dissolved inorganic carbon (DIC) fixation, the estimated nitrogen flux into the deep ocean is about an order of magnitude too low to fuel the measured dark DIC fixation. Thus, the nature and extent of in situ energy sources for chemoautotrophy in the dark ocean are only partially identified and quantified. Seawater collected in the meso- and bathypelagic eastern Atlantic Ocean and incubated at 20˚C exhibited DIC fixation rates up to 500 times greater than rates measured at in situ temperatures. These high rates of autotrophy are not accompanied by an increase in prokaryotic abundance, indicating a probable gene expression response by organisms present in situ. As these incubations were amended solely with $^{14}$C-labeled bicarbonate, it appears there are potential energy sources available in the dark ocean supporting high levels of chemoautotrophy that are not, or not efficiently, utilized at ambient temperatures. In incubation experiments, the temperature dependence of the DIC fixation as well as the accompanying changes in microbial community composition were determined in combination with a metagenomic approach to further constrain the chemoautotrophic potential of the deep ocean.

Department of Marine Biology, University of Vienna, Austria

Presenting author: Gerhard.herndl@univie.ac.at

## DIVERSITY OF *NASA* GENES IN THE GLOBAL OCEANS

Xuexia Jiang and Nianzhi Jiao*

Heterotrophic bacterial utilization of dissolved inorganic nitrogen has profound effects on the flux of N and C in the ocean. In present study, nitrate-assimilating bacteria (NAB) were found widely distributed in various marine environments including coastal, shelf, oceanic hydrothermal vent field and water column (from surface to sediment). Clone library analysis revealed previously underestimated *nasA* diversity and novel *nasA* community composition in different marine environments. The retrieved *nasA* sequences were new and only 36% of the sequences exhibited 90% or more identity with that in the NCBI database. The results suggest that the taxonomic identity of assimilatory nitrate bacteria were far more recognized. The *alphaproteobacterial nasA* sequences occupied approximately 28% of total sequences and distributed in all the sampling sites. Almost all of the *alphaproteobacterial* OTUs were classified into three *Roseobacter*-like groups (I-III). The *nasA* diversity of the mesopelagic and deep waters was higher and depth related sequences were distantly related to known sequences and likely represent novel phylogenetic groups. These data suggested that nitrate is the key factor influencing the *NASA* containing bacteria in the vertical dimension. The NAB community structure varies with local environment and biogeographic patterns were observed using statistical analysis. This study represents the first larger-scale systematic survey of the biodiversity of nitrate assimilating bacteria in the global oceans based on *nasA* genes. These data suggest the local environmental conditions play the most important roles in regulating the community composition and distribution of the nitrate-assimilating bacteria.

State Key Laboratory of Marine Environmental Sciences, Xiamen University, Xiamen 361005, P.R. China.

Presenting author: jiangxuexia@xmu.edu.cn

## RESPONSES OF "BIOLOGICAL PUMP" AND "MICROBIAL CARBON PUMP" TO NUTRIENT PERTURBATIONS IN NATURAL AND ANTHROPOGENIC SCENARIOS

Nianzhi Jiao et al.

The phenomena that upwelling productive regions are often sources rather than sinks of atmospheric $CO_2$ are usually attributed to $CO_2$ out-gassing of upwelled cold $CO_2$-rich water under warm surface conditions. However, actual $CO_2$ effluxes often exceed those by chemical equilibrium and thermodynamic stoichiometry. We hypothesize that upwelling enriched nutrients enhance not only phytoplankton production (POC and DOC) but also heterotrophic microbial metabolisms; that upwellings slowdown POC sinking rate allowing more time for POC mineralization in the euphotic zone; and that the phytoplankton produced labile OC stimulates microbial uptake of bulk OC and consequent respiration. This hypothesis has been examined in the South China Sea (SCS) upwelling areas where POC concentrations in the upper euphotic zones were higher than non-upwelling waters but declined to similar levels at 100m.The sharp POC attenuations were consistent with the lower DO (especially below 50m) / higher consumptions of oxygen (AOU) and accumulations of FDOM than the ambient waters. Bacterial abundance was similar between the upwelling and non-upwelling areas while respiration rates were higher in the former cases. The double-edged effects of nutrients on OC production and consumption were then tested in the mesocosm experiments, and functional genes including *nasA* and ABC transporters, cellular contents of PHA, as well as FDOM and respiration were monitored. The results suggest that excess nutrients are negative for OC sequestration; Therefore optimum nutrient conditions for synergistic effects between biological pump and microbial carbon pump are worth further studies for carbon sequestration in the ocean.

Xiamen University, 422 Siming Nanlu, Xiamen (361005), China

Presenting author: jiao@xmu.edu.cn

## THE MEANING OF DIVERSITY FOR UNDERSTANDING THE MICROBIAL CARBON PUMP IN THE OCEANS

David L. Kirchman

Two of the more important discoveries in biological oceanography have been the high fraction of primary production processed by bacteria and the high phylogenetic diversity of these microbes. Studies conducted mainly in the 1980s and 1990s demonstrated that bacteria process on the order of 50% of all primary production, implying an equally high flux of carbon through dissolved organic material and eventually through bacteria and the rest of the microbial loop. Soon after that discovery, PCR-based studies in the 1990s began to reveal the high diversity of bacteria and other microbes. More recently, metagenomic and other approaches have provided a detailed picture of the taxonomic composition of bacteria and archaea in many of the world's oceans. However, we know much less about the specific biogeochemical role of bacteria and many other microbes in the oceanic carbon flux. This presentation will review past work and present new results from single-cell, tag sequencing, and metagenomic studies that explore the links between microbial community structure and its role in carbon fluxes, including the microbial carbon pump. One conclusion from these studies is that a relatively small number of bacterial taxa are responsible for most of DOM processing in the oceans.

School of Marine Science and Policy, University of Delaware, Lewes, DE 19958 USA

Presenting author: kirchman@udel.edu

## AGEING OF MARINE DISSOLVED ORGANIC MATTER: A MOLECULAR PERSPECTIVE

Boris P. Koch

Composition and distribution of marine dissolved organic matter (DOM), the largest active reservoir of reduced carbon in the ocean (662 Pg), is controlled by primary production, bacterial reworking, water mass mixing, physico-chemical degradation, and aggregation/disaggregation processes. DOM contains and binds to micronutrients such as iron and by that governs element fluxes and primary production and the refractory portion of DOM contributes to carbon sequestration and creates a buffer in the global carbon cycle. It was hypothesized that enhanced DOM turnover contributed to climate warming events in the Eocene. Previous studies also suggest that ocean biomes and their algal species composition affect the bulk inorganic and organic nutrient ratios in the ocean. Hitherto, the immense chemical complexity of DOM prevented a satisfying molecular characterization. Recent advances in molecular methods allowed a better understanding about transformation and preservation of the organic matter. Our results from the Atlantic Ocean suggest that refractory DOM molecules cycle on timescales much longer than the turnover of the bulk DOC pool – therefore creating an efficient buffer in the global organic carbon cycle. With gradual ageing, DOM molecules cover only a narrow range of molecular size and elemental ratios, presumably reflecting the most stable configuration in the oceanic environment.

Alfred Wegener Institute for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany

Presenting author: Boris.Koch@awi.de

## POTENTIAL EFFECTS OF OCEAN WARMING ON THE BIOLOGICAL AND MICROBIAL CARBON PUMPS

Louis Legendre, Lionel Guidi, Julia Uitz

The biological pump (BP) sequesters carbon in water below 2000 m and in sediments. The microbial carbon pump (MCP) sequesters carbon in refractory dissolved organic carbon (RDOC). The flux of particulate organic carbon (POC) in sediment traps at 2000 m (BP) and the rate of RDOC production (MCP) are 0.4 and 0.5-0.6 Gt C per year, respectively.

BP is largely controlled by two rates: export production (EP) from surface, and remineralization (R) of POC during its transit down to 2000 m. These two rates are influenced by the composition of phytoplankton communities: increased phytoplankton production (PP) and EP are generally positively related to increased large-sized PP, and large POC tends to be remineralized faster than smaller POC. Climate change models predict a general shift of phytoplankton toward smaller size, hence general decreases in EP and R. These two changing rates should not cancel each other because phytoplankton size influences more EP than R. We propose that decreased R will reduce the effect of warming on BP.

MCP is mostly influenced by the rate of RDOC production (mostly takes place in surface waters), not the time scale of RDOC downward transport because it is small relative to the residence time of RDOC. RDOC results from microbial transformation of organic carbon (which comes directly or indirectly from PP). Climate change is expected to generally reduce PP and increase microbial activity. We raise the question whether the combination of these two changing rates will reduce or not the effect of warming on MCP.

Villefranche Oceanography Laboratory, BP 28, 06230 Villefranche-sur-Mer, France

Presenting author: legendre@obs-vlfr.fr

## PROBING MICROBIAL CARBON PUMP IN PROTEROZOIC OCEANS

Chao Li

The Proterozoic (2.5-0.542 Ga) oceans were largely stratified and anoxic possibly with sulfidic waters dynamically developed on shelves (Li et al., 2010; Poulton and Canfield, 2011). Because of the lack of multicellular animals and corresponding biological bump effects, the Proterozoic ocean is potentially an ideal candidate for studying the microbial carbon pump (MCP), especially on its biogeochemical mechanisms and ecological effects.

Proterozoic sediments contain abundant records for the MCP. Logan et al. (1995) found that *n*-alkanes preserved in Proterozoic sediments are generally $^{13}$C-enriched relative to coexisting isoprenoids, whereas this pattern is opposite in Phanerozoic (<0.542 Ga). Such a unique isotopic pattern for the Proterozoic can be well explained by intensified heterotrophic degradation of primary *n*-alkyl lipids and subsequent addition of secondary $^{13}$C-rich counterparts in the Proterozoic oceans in which slow sink of primary OM might be responsible given the lack of animal packing effects. Neoproterozoic sediments associated with global glaciations contain the most $^{34}$S-enriched pyrites (Li et al., 2012) and the largest negative C-isotopic excursion (Grotzinger and Fike, 2011) in the Earth history. Both anomalies can be well attributed to the eventual oxidation of the large recalcitrant dissolved organic carbon (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. Fossil records also suggest that the evolution of the early animals (sponges) may have been facilitated by the appearance of the large RDOC pool in the late Neoproteroozic oceans.

State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences, Wuhan 430074, China

Presenting author: ucrchaoli@gmail.com

## AUTOTROPHIC AND HETEROTROPHIC RESPONSES TO IRON AND NUTRIENTS ENRICHMENT IN THE WESTERN PACIFIC OCEAN

Qian Li, Nianzhi Jiao

Iron fertilization has been widely proved to be a driving force for primary production in high-nitrate, low-chlorophyll (HNLC) oceans since Martin's Fe-limitation hypothesis. However, most of the studies focus on phytoplankton rather than bacterioplankton, HNLC habitats rather than low-nitrate, low-chlorophyll (LNLC) scenarios. The present study was aimed at both autotrophic and heterotrophic responses to iron enrichment in conjunction with other nutrients. In situ experiments were conducted in the Western Pacific Ocean (126.0014° E, 18.00267° N) in July 2011, by using Flow Cytometry (FCM), high-performance liquid chromatography (HPLC), fluorescence induction and relaxation system (FIRE) and Technicon AA3 Auto-Analyzer et al. The results indicated that iron could be a limiting factor for phytoplanktonic cells physiology, though the total chlorophyll a (Chl a) was only slightly enhanced. When major macro nutrients (nitrate plus phosphate) or volcanic ash was supplemented, a 2-3 folds increase of Chl a and bacterial abundance, a large enhancement of both particulate organic carbon (POC) and particulate organic nitrogen (PON) was observed while the DOC level maintained the same. HPLC and 16S rDNA clone libraries analysis also confirmed the species composition of phytoplankton and bacteria were affected by different treatments. This study suggested that anthropogenic nutrients enrichment and volcanism, as a way to inject various bio-available nutrients including iron into the surface ocean, can stimulate marine primary production and thus the biogeochemical nutrients cycle.

State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen 361005, China

Presenting author: Liqin00@xmu.edu.cn

## POSSIBLE CHANGES IN THE DYNAMICS OF PARTICULATE CARBON SEQUESTRATION IN THE OPEN OCEAN ASSOCIATED TO ANTHROPOGENIC PERTURBATIONS OF THE ENVIRONMENT

Juan-Carlos Miquel[1], Beat Gasser[1], Jacobo Martín[1]

The complex marine carbon cycle as known at present may suffer alterations from the pressure of changing environmental conditions resulting from anthropogenic activities. The biological pump and the resulting sequestration of $CO_2$, that is, the production in the surface ocean of biological particles that ultimately sink and carry to depth a significant quantity of carbon, may be altered by a number of factors: increase of the amount of $CO_2$ entering the surface ocean from the atmosphere, decrease of $CO_2$ dissolution associated to increasing seawater temperature, increase of acidity of the seawater (decreasing pH) associated to increasing $CO_2$ concentration and its implication in several biological compartments and marine aggregate dynamics. Considering these factors, a review of a two decade time-series of downward flux of particles and carbon export is done and the major factors governing particulate carbon sink are reconsidered in the prospect of future predictable changes in the environment. Special attention will be given to the possible consequence of changing water temperature and acidity on carbon export.

[1]Environment Laboratories, IAEA, 4 quai Antoine 1er, Monaco
[2]Instituto de Ciencias del Mar (ICM-CSIC), Paseo Maritimo de la Barceloneta, 37-49. Barcelona, Spain

Presenting author: j.c.miquel@iaea.org

## THE RISE AND DOMINANCE OF MIXOTROPHIC PROTISTS IN A CHANGING WORLD; REDEFINING THE FUNCTIONALITY OF THE BIOLOGICAL AND MICROBIAL CARBON PUMPS

Aditee Mitra[1*], Kevin J. Flynn[1], Diane K. Stoecker[2], John A. Raven[3], Edna Granéli[4], Patricia M. Glibert[2], Per Juel Hansen[5], JoAnn M. Burkholder[6]

The traditional view of the planktonic foodweb is simple: nutrients are consumed by phytoplankton, that support zooplankton, and ultimately fish. This structure lies at the heart of most models used to explore climate change and fisheries production. Here we question the validity of this historic view, developing a new paradigm for planktonic ecosystems recognising the ecological importance of mixotrophic protists, combining phagotrophy and phototrophy. The traditionally important photoautotrophic eukaryotic plankton and their heterotrophic microzooplankton grazers dominate only within immature environments (e.g., spring bloom in temperate water). With their flexible nutrition, mixotrophs dominate more mature systems (e.g., temperate summer, established eutrophic systems and oligotrophic systems). The foodweb structure dominated by mixotrophs differs fundamentally in its flow of energy and nutrients, with a shortened and more efficient chain from nutrient regeneration to primary production. This revised structure also implicates a review in the functioning of the microbial carbon pump, as it radically alters the dynamics of DOM and of the integration of bacterial and primary production, with bacteria providing a direct conduit from DOM to primary production (and thence to the biological pump). Such a fundamental difference in structure warrants a revision in the way that marine production is modelled, with an explicit description of mixotrophs. An assumption that existing traditional descriptions are fit for purpose becomes increasingly difficult to support when considering climate change scenarios, such as increased stabilisation of the upper water column, which likely see conditions in the oceans changing significantly towards those further promoting the growth of mixotrophs.

[1]Centre of Sustainable Aquatic Research (CSAR), Swansea University, Swansea SA2 8PP, UK
[2]University of Maryland Center for Environmental Science, Horn Point Laboratory, P.O. Box 775, Cambridge MD 21613, USA
[3]Division of Plant Sciences, University of Dundee at the James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK
[4]Marine Sciences Centre, Linnaeus University, 39182 Kalmar, Sweden
[5]Marine Biological Section, University of Copenhagen, Strandpromenaden 5, DK-3000 Helsingør, Denmark
[6]Center for Applied Aquatic Ecology, North Carolina State University, 620 Hutton Street, Suite 104 Raleigh, NC, USA

Presenting author: A.Mitra@swansea.ac.uk

## MICROBIAL LOOP AND CARBON EXPORT IN THE SUBTROPICAL OCEAN

Susanne Neuer

The microbial loop is thought to be the major utilization pathway of phytoplankton in the pico-and nano-size range, especially in the oligotrophic open ocean. There, dilution experiments have shown that most of the primary production is indeed consumed by nano-and micrograzers. As a consequence, this consumption and regeneration pathway should lead to greater retention of primary production of pico-and nanophytoplankton in the euphotic zone, with most of the export production then being left to aggregation of detritus or mesozooplankton fecal pellets. However, research in the subtropical North Atlantic that is based on DNA based molecular identification of sinking particulates collected by shallow trap material has shown that a considerable portion of identifiable taxa are from the smallest eukaryotic phytoplankton, in addition to the photosynthetic prokaryote genera *Prochlorococcus* and *Synechococcus*. This indicates that the distinction between microbial-retention and export is not clear-cut. I will explore in this presentation how to approach this conundrum and how the role of the microbial loop might be influenced by future changes of the ocean, such as warming and greater stratification.

Arizona State University, School of Life Sciences LSE 421, Tempe, AZ 85287-4501, USA

Presenting author: Susanne.Neuer@asu.edu

## STUDYING OXYGEN MINIMUM ZONES IN THE NORTHERN INDIAN OCEAN USING ARGO-OXYGEN DATA

Satya Prakash, Prince Prakash and T.M.Balakrishnan Nair

We have analyzed two Argo-oxygen floats deployed in the northern Indian Ocean, one float from each the Arabian Sea and Bay of Bengal. In the Arabian Sea the oxycline depth shows large seasonal variations: it shoals up every year during the early winter monsoon. Our analysis shows that it may possibly be caused by westward propagating upwelling Rossby waves. In the year 2007, the doming of the thermocline during the winter was aggravated by the presence of an un-named tropical storm. The nutrient rich, oxygen deficient water came as close as 30 m below the sea surface and triggered a bloom (Chl-I >1 mg /$m^3$) in the storm influenced region. Analysis of Argo-oxygen profiles before and after the storm underscores the role of sub-surface remineralisation in generating/maintaining oxygen deficiency in the Arabian Sea. Data from the Bay of Bengal shows that the surface layer in the bay is always under-saturated with oxygen, suggesting an imbalance between air-sea exchange and biological production of oxygen taken together and the net oxygen demand in this layer; the latter seems to be higher in the surface layer. Our analysis also suggests that oxycline variability in the Bay of Bengal is driven by the thermocline depth: the thermocline depth here is positively correlated (0.97) with the oxycline depth and is negative correlated (0.82) with the sea surface height anomaly (SSHA). This shows that oxygen minimum zone in the bay is governed by physical process such as eddies.

Indian National Centre for Ocean Information Services (INCOIS), Prgathi Nagar (BO); Nizampet (SO), Hyderabad – 500 090, India

Presenting author: satyap@incois.gov.in

## NITROGEN AND PHOSPHORUS' EFFECT ON CDOM GENERATED BY BACTERIA: THE IMPLICATION FROM TWO ON-BOARD INCUBATION EXPERIMENTS

Ren Rui, Jiao Nianzhi, Li Zhipeng, Guo Jun

CDOM is the light-absorbing part of DOM. Some evidence suggest N could be an important enhancer to the generation of CDOM, but few studies set their focus on the contribution of phosphorous to CDOM. Here we conduct two on-board incubation experiments on the 2011's and 2012's South China Sea cruise. Our result shows: bacteria could contribute to the generation of CDOM, and even in the open ocean, both N and P could lead to a pulse of CDOM's signal. Bacteria could mediate the transform between different CDOM components. These results suggest: bacteria could effectively participate in the biogeochemical cycle of CDOM, and both N and P have important impact on CDOM's dynamics.

State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen, China, 361005

Presenting author: renruixm@gmail.com

## MICROBIOLOGICAL AND PHOTOCHEMICAL TRANSFORMATION OF ORGANIC CARBON DURING AN IN SITU IRON AND PHOSPHATE ADDITION EXPERIMENT IN THE NORTH ATLANTIC

Carol Robinson[1] and the FeeP team[2]

In order to forecast the influence of climate change on the efficiency of the microbial and biological carbon pump, a broader understanding of the dynamics of nutrient limitation of open ocean microbial foodwebs is required. The present two ship experiment was undertaken to investigate the role of iron and phosphorus on plankton activity and biogeochemical fluxes in the subtropical North Atlantic. In May 2004, the tracer sulphur hexafluoride ($SF_6$) was added together with anhydrous monosodium phosphate to a 25 $km^2$ area west of the Canary Islands. Continual analysis of surface water $SF_6$ concentrations enabled sampling of this amended water body and of adjacent unamended waters for 11 days for the abundance and activity of bacterioplankton, phytoplankton, micro- and meso-zooplankton. A second 7-day experiment involved the addition of $SF_6$, iron sulphate and monosodium phosphate and a similar 'amended' and 'unamended' sampling strategy. Plankton respiration was derived from the *in vitro* decrease in oxygen during a 24 hour dark incubation, and photo-chemical oxygen demand was determined from the decrease in oxygen of a 0.2 µm filtered sample incubated in quartz glass bottles in natural light (ca. 10 hours). This presentation will examine the subtle differences in and timescales of changes in microbial abundance and activity which impact the transformation of organic carbon with and without phosphate addition and between the phosphate and phosphate + iron additions.

[1]School of Environmental Sciences, University of East Anglia, Norwich, UK
[2]Plymouth Marine Laboratory, Plymouth, UK

Presenting author: carol.robinson@uea.ac.uk

## SENSITIVITY OF THE OCEAN BIOLOGICAL PUMP TO PARAMETERIZATIONS OF THE RECYCLING MATTER

Anastasia Romanou[1] and Watson W. Gregg[2]

Sensitivities in modeling the biological pump in the GISS climate model are explored here. Results are presented from twin control simulations of $CO_2$ gas exchange between the ocean and the atmosphere using two ocean models coupled to the same atmosphere (modelE). The two ocean models (Russell ocean model and Hybrid Coordinate Ocean Model, HYCOM) use different vertical coordinate systems, and therefore different representations of column physics. Both variants of the GISS climate model -- modelE with the Russell ocean and modelE with the HYCOM ocean -- are coupled to the same ocean biogeochemistry module (the NASA Ocean Biogeochemistry Model, NOBM) which computes prognostic distributions for biotic and abiotic fields that influence the air-sea flux of $CO_2$ and the deep ocean carbon transport and storage. In particular, the model differences due to remineralization rate changes are compared to differences attributed to physical processes modeled differently in the two ocean models such as ventilation, mixing, eddy stirring and vertical advection. The Southern Ocean emerges as a key region where the $CO_2$ flux is as sensitive to biological parameterizations as it is to physical parameterizations.

[1] Dept of Applied Phys. and Applied Math., Columbia. U. and NASA-GISS, 2880 Broadway, New York, NY10025, USA.
[2] Goddard Institute Space Flight Center – NASA

Presenting author: ar2235@columbia.edu

## EFFECTS OF ANTICYCLONIC EDDY FROM THE KUROSHIO ON THE WINTER PHYTOPLANKTON BLOOM IN THE SOUTH CHINA SEA: AN EDDY-RESOLVING PHYSICAL-BIOLOGICAL MODEL STUDY

Yoshikazu Sasai[1], and Hideharu Sasaki[2]

An eddy-resolving coupled physical-biological ocean model has been employed to investigate physical influences on the phytoplankton blooms in the South China Sea (SCS) during 2000-2007. The model captures the seasonal and interannual variability of surface chlorophyll distribution associated with the mesoscale eddies, ocean circulation and upwelling generated by the monsoon winds. In the northwestern Luzon, the model also reproduces the winter phytoplankton bloom. During boreal winter, the northeasterly winds force the cyclonic gyre in the SCS and result the localized upwelling off the western Luzon. The winter phytoplankton bloom in the northwestern Luzon is induced by the nutrient supply from the subsurface layer by the shallow nutricline depth (Ekman pumping velocity) and upper mixed layer depth entrainment. In addition the anticyclonic eddy separated from the Kuroshio and the Kuroshio intrusion are large effects on the winter phytoplankton blooms. Especially, along the edge of anticyclonic eddy and the Kuroshio Current, the phytoplankton blooms are enhanced. The strong vertical velocity of anticyclonic eddy produces a steep nutrient slope between the edge and the center of eddy and the high nutrient waters is uplifted along this slope. As a result, in the edge of anticyclonic eddy, the filamentary character distribution of high chlorophyll is formed.

[1]Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, 3173-25, Showa-machi, Kanazawa-ku, Yokohama, 236-0001, Japan
[2]Earth Simulator Center, Japan Agency for Marine-Earth Science and Technology, Yokohama, 236-0001, Japan

Presenting author: ysasai@jamstec.go.jp

## ON EXPLOITING THE POTENTIAL OF OCEAN IRON FERTILIZATION EXPERIMENTS FOR TESTING HYPOTHESES ON THE CARBON PUMP AND ECOSYSTEM RESTORATION

Victor Smetacek[1,2], Wajih Naqvi[2]

Ocean iron fertilization (OIF) experiments represent a powerful tool to study ecological and biogeochemical processes under natural conditions in the open ocean. They are the marine equivalent of whole-lake experiments in limnology, the results of which have changed our understanding of aquatic ecosystem functioning and lake management techniques in fundamental ways. Analogous insights into the impacts of higher trophic levels on the marine pelagial are to be expected, as demonstrated by the two OIF experiments EIFEX and LOHAFEX carried out in the same region and season, with initially similar copepod populations, but with totally different effects on the magnitude and depth of the biological carbon pump. In the presence of adequate silicate (EIFEX), only grazer-protected diatoms contributed to iron-induced biomass increase, most of which subsequently sank out to great depths in the form of aggregated dead cells. At limiting silicate concentrations (LOHAFEX), nanoflagellates provided the bulk of new biomass and dissolved organic carbon accumulated in the surface layer with low vertical particle export. Since iron addition stimulated copepod egg production, it is likely that zooplankton biomass, including krill, will increase in larger-scale, longer-term experiments. Testing the zooplankton-iron hypothesis will be of great relevance for ecosystem restoration measures. Unfortunately, OIF experiments have not attracted the scientific interest they deserve because of their geo-engineering implications and the threat of commercialization. However, international regulations are now in place that can curb such ventures so it is hoped that more ambitious OIF experiments addressed at fundamental processes will be carried out soon.

[1]Alfred Wegener Institute for Polar and Marine Research of the Helmholtz Centre, 27570 Bremerhaven, Germany
[2]CSIR National Institute of Oceanography, Goa, India

Presenting author: Victor.Smetacek@awi.de

## DISTRIBUTION AND FUNCTION OF GENES RELATED TO MICROBIAL DISSOLVED ORGANIC MATTER UTILIZATION: ONE CASE OF TONB-DEPENDENT TRANSPORTERS

Kai Tang, Nianzhi Jiao

Bacteria play critical roles in marine carbon cycles by microbial carbon pump mechanisms （MCP） incorporating and redistributing dissolved organic matter (DOM) and inorganic nutrients in the oceans. TonB-dependent transporter (TBDT) proteins allow Gram-negative bacteria to uptake scarce resources from nutrient-limited environments. We report the distribution of encoded known and putative TonB-dependent transporter (TBDT) proteins in microorganism's genomes and Global Ocean Survey (GOS) data. TBDT sequences were mainly classified into three groups with a Lek clustering algorithm and substrate specificities: (1) DOM transporters, (2)Siderophores/Vitamins transporters, (3)Heme/Hemophores transporters. The study indicates that *Gammaproteobacteria* and CFB group bacteria account for the TBDT gene pool in marine surface waters. These findings, derived from 57 GOS sites, confirm the ecological importance of TBDT in DOM assimilation and siderophore transportation in marine. The study provides insights into the linkage between molecular characterization and microbial DOM utilization.

State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen 361005, People's Republic of China

Presenting author: tangkai@xmu.edu.cn

## UNDERSTANDING CONTROLS OF DIEL PATTERNS OF BIOLOGICAL $CO_2$ FIXATION IN THENORTH ATLANTIC OCEAN

Helmuth Thomas[1], Susanne E. Craig[1], Blair J. W. Greenan[2], William Burt[1], Gerhard J. Herndl[3,4], Simon Higginson[1], Lesley Salt[4], Elizabeth H. Shadwick[1,5], and Jorge Urrego-Blanco[1]

Much of the variability in the surface ocean's carbon cycle can be attributed to the availability of sunlight, through processes such as surface heat flux and photosynthesis, which regulate carbon flux over a wide range of time scales. The critical processes occurring on timescales of a day or less, however, have undergone few investigations, and most of these have been limited time spans of several days to months. Optical methods have helped to infer short-term biological variability, but corresponding investigations of the oceanic $CO_2$ system are lacking. We employ high-frequency $CO_2$ and optical observations covering the full seasonal cycle on the Scotian Shelf, Northwestern Atlantic Ocean, in order to unravel diel periodicity of the surface ocean carbon cycle and its effects on annual budgets. Significant diel periodicity ion the surface $CO_2$ system occurs only if the water column is sufficiently stable as observed during seasonal warming. During that time biological $CO_2$ drawdown, or net community production (NCP), are delayed for several hours relative to the onset of photosynthetically available radiation (PAR), due to diel cycles in Chlorophyll *a* concentration and to grazing. In summer, NCP decreases by more than 90%, coinciding with the seasonal minimum of the mixed layer depth and resulting in the disappearance of the diel $CO_2$ periodicity in the surface waters.

Ongoing work focuses on the transfer of these patterns to the individual -ideally remotely detectablebiological species, responsible for the CO fixation at the seasonal scale in order to predict vulnerability of the system due to climate change.

[1]Dalhousie University, Department of Oceanography, Halifax, NS, Canada
[2]Bedford Institute of Oceanography, Fisheries & Oceans Canada, Dartmouth, NS, Canada
[3]University of Vienna, Department of Marine Biology, Vienna, Austria
[4]Royal Netherlands Institute for Sea Research, Department of Biological Oceanography, Texel, The Netherlands
[5]Antarctic Climate & Ecosystems Cooperative Research Centre, University of Tasmania, Hobart, Tasmania, Australia

Presenting author: helmuth.thomas@dal.ca

## ROLE OF MESO-SCALE EDDIES ON THE VARIABILITY OF BIOGENIC FLUX IN THE NORTHERN AND CENTRAL BAY OF BENGAL

P. J. Vidya and S. Prasanna Kumar
National Institute of Oceanography, Dona Paula, Goa-403 004, India.

Presenting author: pjvidya@gmail.com

Mesoscale eddies are ubiquitous in the Bay of Bengal and they are expected to play a major role in the export of organic carbon. However, their contributions to the carbon export to the deep ocean are yet to be quantified. In the present study we explore the role of mesoscale eddies on the variability of biogenic flux in the northern and central Bay of Bengal using the data obtained from sediment traps located at 17°27'N, 89°13'E and 13°07'N, 84°24'E respectively. The biogenic flux data in the northern Bay of Bengal trap (NBBT) was for a period of 5 years from February 1994 to December 1998, while that at the central Bay of Bengal trap (CBBT) was for a period of 3-and-half years from January 1993 to June 1996. Analysis of temporal variation of the biogenic opal and calcium carbonate fluxes suggest that though mesoscale eddies enhance both diatom and coccolithophore, organic carbon export is directly correlated to the diatom blooms. Although, spatial size and life span of the cyclonic eddies are different in both the regions, their contribution to total carbon export was estimated to be 40%. We propose that in the Bay of Bengal, cyclonic eddies help to sustain/make the region as a strong sink of $CO_2$ via diatoms.

Presenting author: pjvidya@gmail.com

## THE ECOLOGICAL EFFECTS OF MARINE MICROBIAL AGGREGATES

Xiaoxue Wang

Microbes in the natural environment form microbial aggregates such as biofilms, flocs ("planktonic biofilms") and sludge. The ecological effects can be viewed from two different aspects: the formation and the dispersal of microbial aggregates.

Many marine bacteria produce polysaccharides which help bacteria attach to biotic and abiotic surface to form microbial aggregates. The matrix of the aggregate is known as “extracellular polymeric substances” (EPS), composed of polysaccharides, proteins, nucleic acids, lipids, signaling molecules *et al*. As component of the cohesive, three-dimensional polymers that interconnects cells, they appears to be mainly refractory dissolved organic carbon in nature as they cannot be further utilized as nutrients. When the aggregates continue to grow and scales up to the size of fast-settling particles, they start to precipitate as a potential sink of marine dissolved organic carbon. “Marine snow” and “Microbial mats” are initially formed by biofilms of surface bacteria, and previous research showed that extracellular polysaccharide produced by marine snow- forming bacteria attracts other exopolymeric particles plankton and diatoms. This process help sequester carbon to the deep ocean. The microbial aggregates can also disintegrate in response to environment changes, and this process involves the release of EPS including polysaccharides, D-amino acids, and signaling molecules into the water phase.

Further studies on the ecological effects of the formation and dispersal of microbial aggregates are warranted. Understanding how environmental factors change the cortisol of marine microbe will help us to probe the changes of carbon sequestration in surface water and in deep water.

The South China Sea Institute of Oceanology, Chinese Academy of Sciences
164 Xingang Xi, Guangzhou, Guangdong Providence, 510301, China

Presenting author: xxwang@scsio.ac.cn

**CARBON EXPORT ALGORITHM ADVANCEMENT IN MODELS**

V.C.Yumruktepe and B. Salihoglu

The rate at which anthropogenic $CO_2$ is absorbed by the oceans remains a critical question under investigation by climate researchers. Construction of a complete carbon budget, requires better understanding of air-sea exchanges and the processes controlling the vertical and horizontal transport of carbon in the ocean, particularly the biological carbon pump. Improved parameterization of carbon sequestration within ecosystem models is vital to better understand and predict changes in the global carbon cycle. Due to the complexity of processes controlling particle aggregation, sinking and decomposition, existing ecosystem models necessarily parameterize carbon sequestration using simple algorithms. Development of improved algorithms describing carbon export and sequestration, suitable for inclusion in numerical models, is ongoing within the framework of the FP7 BASIN programme. Existing unique algorithms used in three state-of-the art ecosystem models ERSEM, PISCES and MEDUSA have been compared and tested against observational data collected at the PAP mooring site. For testing purposes, algorithms were inserted into a common 1D pelagic ecosystem model. Following comparison of existing algorithms, new experimental results obtained from targeted mesocosm experiments and open ocean observations, will be utilized to develop improved formulations. New algorithms will be compared to existing model formulations using a standard validation data set complied within the framework of BASIN. In order to assess algorithm response under differing hydrographic environments, each set of algorithms will be tested within a 1D framework at three sites in the N Atlantic (PAP, ESTOC and BATS). Ultimately it is intended to feed improved algorithms to the 3D modelling community, for inclusion in coupled numerical models.

Middle East Technical University Institute of Marine Sciences, Physical Oceanography, ODTU Deniz Bilimleri Enstitusu PK28, 33731 Mersin, Turkey.

Presenting author: caglar@ims.metu.edu.tr

## RESPONSE OF BACTERIOPLANKTON COMMUNITY STRUCTURE TO AN ARTIFICIAL GRADIENT OF $pCO_2$ IN THE ARCTIC OCEAN

R. Zhang[1,], X. Xia[1,]*, S.C.K. Lau[2], C. Motegi[3], M.G. Weinbauer[3], N Jiao[1]

The influences of ocean acidification on bacterial diversity were investigated using DNA fingerprinting and clone library analysis of bacterioplankton samples collected from the largest $CO_2$ manipulation mesocosm study (EPOCA) that had been performed thus far. Terminal restriction fragment length polymorphism analysis of the PCR amplicons of the 16S rRNA genes revealed that bacterial diversity, species richness and community structure varied with the time of incubation but not the degree of ocean acidification. The phylogenetic composition of the major bacterial assemblage after a 30-day incubation under various $pCO_2$ concentrations did not show clear effects of $pCO_2$ levels. However, the maximum apparent diversity and species richness which occurred during incubation differed in the high and low $pCO_2$ treatments, in which different bacterial community structure harbored. In addition, total alkalinity was one of the contributing factors for the temporal variations in bacterial community structure observed during incubation. A negative relationship between the relative abundance of *Bacteroidetes* and $pCO_2$ levels was observed for samples at the end of the experiment. Our study suggested that ocean acidification affected the development of bacterial assemblages and potentially impacts the ecological function of the bacterioplankton in the marine ecosystem.

[1]State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen 361005, PR China

[2]Division of Life Science and Division of Environment, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong SAR, PR China

[3]Microbial Ecology and Biogeochemistry Group, Université Pierre et Marie Curie-Paris 6, Laboratoire d'Océanographie de Villefranche, 06230 Villefranche-sur-Mer, France; CNRS, Laboratoire d'Océanographie de Villefranche, 06230 Villefranche-sur-Mer, France

*These authors contributed equally to this work.

Presenting author**:** ruizhang@xmu.edu.cn

Authors of correspondence: jiao@xmu.edu.cn; wein@obs-vlfr.fr

**PRODUCTION OF EXOPOLYSACCHARIDE BY MARINE BACTERIA**

Zilian Zhang, Zhipeng Li，Yi Chen and Nianzhi Jiao

Refractory dissolved organic carbon (RDOC), which accounts for around 90% of the dissolved organic carbon (DOC), is the largest reservoir of fixed carbon in the ocean. Microbial generation of RDOC by microbial carbon pump (MCP) has been established. However, the detailed molecular mechanism is yet to be further illustrated. It was indicated polysaccharides are relative abundant components of seawater DOC. Many marine bacteria produce exopolysaccharide (EPS). To elucidate their roles on the marine carbon sequestration, EPS producing marine bacteria were isolated from seawater collected from Western Pacific Sea and South China Sea. Bacteria belonged to genus of *Alteromonas*, *Bacillus*, *marine*, *Pseudoalteromonas*, *Pseudomonas*, *Oceanicaulis, Ruegeria,* etc. were isolated. Gamma proteobacteria are the dominant bacteria isolated. The EPS productivity of a strain named as *Alteromonas* sp. JL2069 was analyzed detail. The JL2069 cells were aggregated and formed large particulate organic matter (POM) during the cultivation. The result suggested that marine bacteria may be involved the carbon sequestration by producing recalcitrant compound such as EPS or/and POM though the mechanisms of MCP and biological pump.

State Key Lab of Marine Environmental Science, Xiamen University, 422 Siming Nan road, Xiamen 36100, China

Presenting author: zhangzilian@xmu.edu.cn

# Workshop 3: Understanding and forecasting human-ocean-human interactions, drivers and pressures, with respect to global change

**Chair: Alida Bundy**

From biogeochemical cycles through foodweb interactions to human use of the oceans, dependent societies and governments there is a complex set of drivers, responses and interactions at multiple levels and scales. In a marine world increasingly affected by global change, the need to develop understanding of this complexity is paramount. Approaches must necessarily be inter- and transdisciplinary, from local to global and at multiple scales. They can include broad comparative studies and in-depth case studies, modelling and empirical indicator approaches or statistical analyses. The overall aim is to link the effects of global change through natural systems and humans systems, identifying their interconnections, vulnerabilities and to create understanding of the possible futures of these interrelated social, ecological and biogeochemical systems in the continental margins and in the open ocean. Our overall objective is to build on this scientific understanding and explore the best strategies and methodological approaches to mitigate or adapt to the changes by means of developing information products useful to policy and decision makers.

To achieve this objective this session brings together experts from a range of natural and social sciences to discuss how to adapt to, and mitigate, the effects of global change on marine ecosystems and the human communities with which they interact; to identify methodological frameworks to aid decision making, to identify the key challenges to progress in this area and to discuss potential ways ahead.

This workshop has three broad themes:

1. Analysis of societal changes in response to, or anticipation of, global change
2. Identification of vulnerabilities to global change, evaluation of current capacities to address global change and societal response to global change
3. Identification of key governance and policy thematic foci to empower societies to address global change

Within these themes we address three overarching questions:

1. Taking into account the biogeochemical changes that are occurring in the shelf and oceanic waters, how can human societies optimize their capacity to adapt to global change?
2. Do we need an integrative human-ocean-human framework?
3. How can natural and social scientists optimize their cooperation to achieve integrated knowledge and understanding of the interactions between the natural and human systems to support proactive policy decisions?

We address these themes and questions using a range of formats including oral presentations, posters, discussions sessions, café-style discussions and breakout

groups. Our objective is to maximize the opportunity for everyone to contribute their ideas interactively with colleagues across the diversity of disciplines represented at IMBIZO III. We invite all participants to contribute to a special issue of “Regional Environmental Change” on the theme “Global change, human-ocean interactions and ways forward”.

**Workshop 3 Conveners**

| | |
|---|---|
| Alida Bundy | (Bedford Institute of Oceanography, Canada) |
| Ratana Chuenpagdee | (Memorial University, Canada) |
| Liana McManus | (Private Consultant, USA) |
| Sarah Cooley | (Woods Hole Oceanographic Institution, USA) |
| Marie-Caroline Badjeck | (Natural Resources Canada, Canada) |
| Bernhard Glaeser | (German Society for Human Ecology, Germany) |

**Workshop 3 Plenary Speaker**

| | |
|---|---|
| Moenieba Isaacs | (University of Western Cape, South Africa) |

## Workshop 3
## Human-ocean-human interactions with respect to global change

| DAY 1 - Monday 28 January | |
|---|---|
| 08:00-09:00 | IMBIZO lll Registration |
| 09:00-09:15 | Welcome – **Eileen Hofmann, Alida Bundy and Kon-Kee Liu** |
| 09:15-10:00 | Workshop 1 Keynote presentation: Ocean hypoxia from physics to fish – **Curtis Deutsch** |
| 10:00-10:45 | Workshop 1 Keynote presentation: Nutrients, hypoxia and fisheries: lessons about multiple stressors from the Chesapeake and beyond – **Denise Breitburg** |
| 10:45-11:15 | *Coffee break* |
| 11:15-12:00 | Workshop 2 Keynote presentation: Microbial carbon pump and ecosystem connectivity – **Farooq Azam** |
| 12:00-12:45 | Workshop 3 Keynote presentation: "ADApT or Die": Finding methodologies to secure the livelihoods and food security for fisheries dependent communities around the world – **Moeniba Isaacs** |
| 12:45-13:45 | *Lunch* |
| 13:45-14:10 | Workshop 3: Introduction, workshop overview and objectives – **Alida Bundy** |
| 14:10-17:00 | **Session 1 - Chair: Alida Bundy**<br>**Analysis of societal changes in response or anticipation of global change** |
| 14:10-14:30 | Socio-economic impacts of artificial reefs on the small scale fishers in peninsular Malaysia - **Gazi Md. Nurul Islam** |
| 14:30-14:50 | Socio-economic evaluation of fisheries in Turkey between 1970 and 2010 – **Ayse Gazihan Akoğlu** |
| 14:50-15:10 | Assessment of health safety from ingestion of Polonium-210 in *Penaeus merguiensis* from a coal burning power plant area of Malaysia - **Lubna Alam** |
| 15:10-15:15 | Poster presentation: Economics of adaptation of sea cucumber fishers in the Philippines to climate change - **Maria Rebecca Campos** |
| 15:15-15:20 | Poster presentation: Climate Change Scenarios and the anchovy fishery in northern Chile - **Eleuterio Yañez** |
| 15:20-15:30 | General discussion |
| 15:30-16:00 | *Coffee break* |
| 16:00-17:00 | **Discussion 1: - Chair: Alida Bundy**<br>How do coastal societies respond to the changing physical and ecological dynamics of open ocean and shelf waters? |
| 17:00-18:00 | **Plenary session discussion – Chair KK Liu, Rapporteur: Karen Wishner**<br>How do biogeochemistry and ecosystems interact in response to natural or man-induced forcing in continental margins and how can such knowledge forge better management of the marine realm? |
| 18:00-19:30 | *Ice Breaker and poster session* |

| **DAY 2 - Tuesday 29 January** | |
|---|---|
| 09:00-17:00 | **Session 2 - Chair: Liana McManus**<br>**Identification of vulnerabilities to global change and evaluation of current capacities to address these** |
| 09:00-09:30 | Reduced pressure in the Israeli coastal ecosystem - Remediation by means of policy change – **Dror L. Angel** |
| 09:30-10:00 | Understanding barriers and drivers for better governability of Mediterranean sea – **Katia Frangoudes** |
| 10:00-10:30 | Analysis of vulnerabilities and adaptation of fishing villages in the Philippines to climate change – **Maria Rebecca Campos** |
| 10:30-11:00 | *Coffee break* |
| 11:00-11:30 | Exploring human-environmental interactions in small-scale fisheries: Implications for managing toward sustainability –**Jack Kittinger** |
| 11:30-12:30 | **Discussion 2** - **Chairs: Liana McManus and Sarah Cooley**<br>How vulnerable are coastal societies to changing dynamics of open ocean and shelf waters? |
| 12:30-13:30 | *Lunch* |
| 13:30-14:00 | Livelihood strategies and access to basic services of fishers in post conflict north and east of Sri Lanka - **Mohamed Munas** |
| 14:00-14:30 | Steps towards a social-ecological coastal typology – **Bernhard Glaeser** |
| 14:30-15:00 | Islands and oceans. Potentials for adapting to global change – **Marion Glaser** |
| 15:00-15:30 | *Coffee break* |
| 15:30-16:00 | Should climate engineering be considered to deal with climate change? An earth system model evaluation of multiple climate engineering approaches - **David Keller** |
| 16:00-17:00 | **Discussion 3: - Chairs: Liana McManus and Alida Bundy**<br>How do coastal communities cope, anticipate and adapt to the changing states of the open and coastal oceans? |
| 17:00-18:00 | **Plenary session discussion – Chair: Helmuth Thomas**<br>How may current understanding of deep ocean processes translate to better assessment and stewardship of fundamental ecological services that deep oceans provide? |
| 18:00-19:30 | *Poster session & BBQ* |

| **DAY 3 - Wednesday 30 January** | |
|---|---|
| 09:00-14:30 | **Session 3 - Chair: Ratana Chuenpagdee**<br>**Identification of key governance and policy thematic foci to empower societies to address marine environmental change** |
| 09:00-09:20 | Local adaptation and mitigation measures for the global change vulnerability: a case study of Andhra Pradesh, India - **Shailendra Kumar Mandal** |
| 09:20-9:40 | Regime shifts in coastal-marine systems and the implications for governance - **Prateep Kumar Nayak** |
| 09:40-10:00 | Working through complexity: a typology for strengthening coastal governance in the context of climate change - **Heidi Schuttenberg** |
| 10:00-10:20 | Building non-linear scenarios for marine futures - **Laurence Mee** |
| 10:20-10:30 | General Discussion |
| 10:30-11:00 | *Coffee break* |
| 11:00-11:20 | Navigating the turbulent waters of the Anthropocene: A deliberative praxis of coastal and ocean governance – **Bruce Glavovic** |
| 11:20-12:35 | Café-style discussions in small groups with each presenter (5 x 15 minutes) |
| 12:35-13:30 | *Lunch* |
| 13:30-14:30 | **Discussion 4 - Chairs: Ratana Chuenpagdee and Bernhard Glaeser** How can governance and policy minimize the vulnerability of coastal communities? |
| 14:30-17:00 | **Session 4 - Chair: Ratana Chuenpagdee**<br>**Methodological approaches - what works for you?** |
| 14:30-15:10 | **Discussion 5 - Chairs: Ratana Chuenpagdee and Bernhard Glaeser**<br>Do we need an integrative human-ocean-human framework? |
| 15:10-15:30 | *Coffee break* |
| 15:30-16:30 | **Discussion 6 - Chairs: Alida Bundy and Ratana Chuenpagdee**<br>ADApT as an integrative HOH framework - Critique and response |
| 16:30-17:00 | Report back and summary |
| 17:00-18:00 | **Plenary session discussion – Chair: Alida Bundy**<br>How can natural and social scientists optimize their cooperation to achieve usable and integrated knowledge and understanding to support policy making and form viable feedback loops between the natural system and human society? |
| 19:30-24:00 | *IMBIZO lll dinner – Hawaii Beach Restaurant* |

| **DAY 4 - Thursday 31 January** | |
|---|---|
| 09:00-12:30 | **Session 5 – Chairs: Alida Bundy and Ratana Chuenpagdee**<br>**Discussion and synthesis** |
| 09:00-10:30 | Panel Discussion: Human-ocean-human interactions with respect to global change<br>(Joint session between Workshop 1 and Workshop 3) |
| 10:30-11:00 | *Coffee break* |
| 11:00-12:30 | Synthesis session for Final Plenary Session:<br>Identify best practises; challenges; ways ahead…<br>Synthesis paper from the workshop<br>Papers for special issue of Regional Environmental Change |
| 12:30-13:30 | *Lunch* |
| 13:30-15:00 | Final plenary session<br>Summary reports from Workshops 1, 2 and 3 and plenary discussion sessions |
| 15:00 | Closing comments, end of meeting |

**Legend:**

| |
|---|
| IMBIZO joint sessions |
| Workshop session themes |
| Joint social activities |
| Discussion sessions |

## ASSESSMENT OF HEALTH SAFETY FROM INGESTION OF POLONIUM-210 IN *PENAEUS MERGUIENSIS* FROM A COAL BURNING POWER PLANT AREA OF MALAYSIA

Lubna Alam[1], Mazlin Bin Mokhtar[1] and Che Abd. Rahim Mohamed[2]

Seafood and their products are considered to be one of the major sources of protein for coastal public and have high export significance. Marine organisms have the capability of accumulating radionuclides from water, and that is why the determination of radioactivity in marine food supplies presumed to be greater importance. Among the various radionuclides occurring in the marine environment, Po-210 assumes greater importance because of their high accumulation potential, especially in seafoods. Therefore a systematic study carried out to estimate the accumulation of Po-210 in popular seafood, *Penaeus merguiensis,* collected from a coal burning power plant area of Malaysia. The Po-210 activity in *Penaeus merguiensis* ranged from 16.81±0.75 to 108.02±4.82 $Bqkg^{-1}$. The Kruskal-Wallis test ($\chi^2$) revealed that there was no statistically significant difference in case of Po-210 activity between the different sampling periods. Po-210 concentration in shrimp maintained a good agreement with the ambient water concentration which indicates the impact of environment on the concentration of Po-210 in shrimp. The concentration of Po-210 in *Penaeus merguiensis* is comparatively higher than that of other places of the world which indicate the impact of coal burning. In this study the committed effective dose has been calculated to estimate the impact of seafood consumption which revealed comparatively higher value. Therefore it is assumed that the seafood consuming populace of coal burning power plant area might be at considerable risk.

[1]Institute for Environment and Development (LESTARI), National University of Malaysia, Bangi, 43600, Selangor

[2]Marine Ecosystem Research Centre (EKOMAR), Faculty of Science and Technology, National University of Malaysia, Bangi, 43600, Selangor

Presenting author: lubna_762120@yahoo.com

## REDUCED PRESSURE IN THE ISRAELI COASTAL ECOSYSTEM - REMEDIATION BY MEANS OF POLICY CHANGE

Dror Angel, Shirra Freeman

The Israeli coastal ecosystem is subject to both natural and anthropogenic pressures, and the composition and abundances of the marine biota are a reflection of these pressures. Many endemic fishes and invertebrates are over-fished or disturbed, resulting in marine communities that consist of large numbers of invasive species. These include "Lessepsian" migrants and alien species that may alter the marine environment even more, such as the stinging scyphomedusan *Rhopilema nomadica* and the venomous marine catfish *Plotosus lineatus*. Many of the invasives affect not only the marine ecosystem but also some key ecosystem services that humans rely on, such as fisheries, water quality, recreational resources, etc. In light of these impacts it would seem easy to convince decision makers to implement the necessary changes to remedy the situation, but this is not the case. We use the **DPSIR** framework [**D**riving forces (e.g. industrial production), **P**ressures on the environment (e.g. sewage), **S**tate of the environment (e.g. marine water quality), **I**mpacts on ecosystems (e.g. fish die offs), **R**esponse of society (e.g. coastal protection)] to help describe the state of the environment in light of human interests and actions and as a means to demonstrate how societal response, such as a change in policy may be used to ameliorate the situation. If, for example, we assume that the success of some invasive fishes is related to overfishing of indigenous species, a moratorium on fishing (policy change) during the reproductive season of the indigenous fishes could help restore these and other ecosystem services.

University of Haifa, Charney School of Marine Sciences, Mt Carmel, 31905 Haifa, Israel

Presenting author: adror@research.haifa.ac.il

## ANALYSIS OF VULNERABILITIES AND ADAPTATION OF FISHING VILLAGES IN THE PHILIPPINES TO CLIMATE CHANGE

Maria Rebecca A. Campos

More than half a million small fishers in the Philippines have been availing of loans the Department of Agriculture. The financing scheme has been quite successful, with 95% repayment rate. However, climate change has affected the productivity of fisheries, thus hindering fishers from paying and renewing their loans. Failure to access credit could greatly inhibit them from continuing to venture on fishing activities and could eventually jeopardize the welfare of their entire households. The inability of creditors to pay their loans and meet their obligations also impairs, to a large extent, the financial operation and viability of the lending institutions. This study analyzes the vulnerability and adaptation practices of these fishers and recommends mitigation mechanisms to minimize the impact of climate change through a bridge financing scheme that will enable fishers to carry on their livelihood activities and support their families' basic needs, while slowly recovering from their losses.

University of the Philippines Open University, Faculty of Management and Development Studies, 10996 Campos Compound, Faculty Village, UPLB, College, 4031 Los Banos, Philippines

Presenting author: cmaribec@yahoo.com

## ECONOMICS OF ADAPTATION OF SEA CUCUMBER FISHERS IN THE PHILIPPINES TO CLIMATE CHANGE

Maria Rebecca A. Campos

The Philippines is the second major producer and exporter of sea cucumbers in the world, including Japan. However, changes in its aquatic environment brought about by climate change has affected this industry and has decreased income for the country's economy, the commercial fishing sector as well as marginal fishermen who rely on it as their source of livelihood. Three types of sea cucumber fishing techniques are commercial fishing, harvesting sea cucumbers as by-catch and by gleaning. In gleaning, collection is done by small-scale or artisanal fishers involving men, women and children who have no control of the shallow coral reef flats where they catch sea cucumbers. This activity is carried out during low tide in shallow intertidal reef flats. Gleaning is often classified as "informal" work acting as a safety net for the rural landless. The community of sea cucumber fishers in Sorsogon organized themselves and came up with two options, using the marine protected area approach: artificial reef or ranch model. The ranch model is now being implemented with an IRR of 40%, BCR 1.7, NPV of PhP 670,000 and payback in more than a year over the first which has negative NPV and payback in over 50 years.

University of the Philippines Open University, Faculty of Management and Development Studies, 10996 Campos Compound, Faculty Village, UPLB, College, 4031 Los Banos, Philippines

Presenting author: cmaribec@yahoo.com

## SOCIO-ECONOMIC EVALUATION OF FISHERIES IN TURKEY BETWEEN 1970 AND 2010

Ayse Gazihan Akoğlu, Barış Salihoğlu, Ekin Akoğlu, Temel Oğuz

Turkey has a coastline over 8,000 km and is surrounded by partially connected but contrasting marine ecosystems (the Black Sea, the Sea of Marmara, the Aegean Sea and the Mediterranean Sea) which have been traditionally and economically important fishing zones for local people throughout the Anatolian history. However, in the 2$^{nd}$ half of the 20$^{th}$ century, the population of the country grew so as to double itself, which, in turn, has lead to an ever-increasing fishing pressure on the fish stocks in its exclusive economic zone (EEZ). Intriguingly, fishery yields showed fluctuating behavior with abrupt rises and falls, which might seem irrespective to the changes in fishing effort at a first glance. Furthermore, it should be underlined that today's catch per unit effort (CPUE) is almost half of the value in ‘70s; nevertheless, the fishing effort has increased more than five-fold. In this study, we elaborate the socio-economic investigations on the demographic structure of the fisheries sector in Turkey to explain the underlying reasons of aforementioned changes in historical fisheries statistics and the progressions of fish stocks in Turkish waters.

Institute of Marine Science, Middle East Technical University, PK 28, Erdemli, Mersin-Turkey

Presenting author: ayse@ims.metu.edu.tr

## STEPS TOWARDS A SOCIAL-ECOLOGICAL COASTAL TYPOLOGY

Bernhard Glaeser, Marion Glaser

An attempt is made to develop a coastal social-ecological typology. In a first step, multiple levels and scales which apply to coasts are reviewed. Multiple scales range from nested hierarchies on spatial, temporal, jurisdictional and institutional scales to non-inclusive and also non-hierarchical scales such as ecosystem outputs, social and technological scales. A current major challenge is the issue-specific identification of key cross-level and cross-scale interactions which shape social-ecological dynamics, patterns and connectivities. An explicitly regional focus is taken in order to explore how a regionally grounded, multi-scale analysis may support multi-level local to global sustainability efforts. Social-ecological sustainability problems are caused by drivers from multiple levels of the earth system.

In our definition, a social-ecological system (SES) consists of a biogeophysical territory, an identified issue/problem and the associated social agents and institutions. Through the problem focus, an SES can extend across disciplines as well as across spatial and institutional levels and scales. A “global sustainability research matrix” which is based on ecozones and problem types can thus be constructed. The regional application of the problem-focused SES definition has the advantage of directly linking to stakeholder agendas at the level where problems are identified. Specific generic problems of tropical CM-SES are overfishing, degrading water quality, coastal poverty and climate change. It is argued that some of the central functions of CM-SES are resource provision, livelihood access, species nursery, carbon sink and storm and erosion protection which need special attention in a social-ecological coastal typology.

German Society for Human Ecology (DGH), IMBER-HDWG, Clayallee 271, 14169 Berlin, Germany

Presenting author: bernhardglaeser@gmail.com

## ISLANDS AND OCEANS. POTENTIALS FOR ADAPTING TO GLOBAL CHANGE

Marion Glaser, Ian Carruthers, Don Forbes, Hartwig Kremer, Alice Newton, Ramesh Ramachandran, Eric Wolanski

Multiple and synergistic global change pressures including climate change, coastward migration, population growth, resource overexploitation, pollution and extreme events are affecting oceans and coasts world-wide. In the marine environment, small islands share a number of physical, socio-economic, and cultural commonalities. Islands can also be divided into archetypes, each giving rise to a different set of complexities. This presentation argues that islands, as a broader category, can be understood as microcosms of different coastal change scenarios and as social nodes for improved ocean management. Island characteristics can contribute to or constrain sustainable development. Island territories, with their high interface with the oceans, and with their often high human dependence on the ocean may also assume important functions in marine management. The presentation introduces an island typology which distinguishes different possible social, economic, institutional, ecological and geo-physical attributes of islands. It then discusses some central differentiating features of islands that are important for a) island ability to cope with global change pressures and the "grand challenges for future earth research; and b) island capacity to contribute to the global challenge of marine and ocean management. Case examples from tropical atoll and reef-fringed islands demonstrate the range of coping and sustainability-enhancing strategies of different island archetypes and their potentials for marine management. We show that an understanding of islands as microcosms of possible human-nature relations in the oceanic environment can help to develop innovative approaches to ocean governance which use so far under-recognised island potentials as self-organizing social-ecological systems in the marine environment.

Centre for Tropical Marine Ecology, Social-Ecological Systems Analysis Group, Fahrenheitstr 6, 28359 Bremen, Germany

Presenting author: marion.glaser@zmt-bremen.de

## NAVIGATING THE TURBULENT WATERS OF THE ANTHROPOCENE: A DELIBERATIVE PRAXIS OF COASTAL AND OCEAN GOVERNANCE

Bruce C. Glavovic

This is the age of the Anthropocene. Human actions have transformed global biogeochemical processes and life-support systems and, paradoxically, past and prevailing development efforts imperil future human well-being. The coastal zone is the frontline of this global sustainability crisis; and continental margins are the new frontier of exploitation. Coastal and oceanic resources offer a cornucopia of opportunities. The pre-eminent challenge of the 21st Century is to realise this potential whilst building resilience and sustainability. Business as usual is untenable. This paper presents case studies of efforts to navigate the turbulent waters of the Anthropocene. Our understanding of coastal development and disaster risk needs to be reframed, and the governance processes that shape resilience and sustainability on coastal margins need to be transformed. Insights from political ecology and post-normal science shed light on how to build harbours of safe refuge on the coastal frontline, and chart a course for sailing the stormy seas of the oceanic frontier. This is, however, a complex and contested endeavour. Conflict, change, uncertainty and surprise are 'normal'. Coastal and ocean management needs to be reconceptualised as a transformative practice of deliberative governance. A conceptual framework, founded on four deliberative outcomes, is presented. First, human and social capital needs to be built through issue learning and enhanced democratic attitudes and skills. Attention then needs to be focused on facilitating community oriented action and improving institutional capacity and decision-making. Together these endeavours enable improved community problem-solving. The ultimate process goal is to build more collaborative coastal and maritime communities. Institutionalising a praxis of deliberative governance will chart new sustainability pathways and help to reduce disaster risk on coastal margins.

EQC Chair in Natural Hazards Planning, School of People Environment and Planning, Massey University, Private Bag 11 222, Palmerston North 4442, New Zealand

Presenting author: b.glavovic@massey.ac.nz

## "ADAPT OR DIE": FINDING METHODOLOGIES TO SECURE THE LIVELIHOODS AND FOOD SECURITY FOR FISHERIES DEPENDENT COMMUNITIES AROUND THE WORLD.

Moenieba Isaacs

Marine resources play a key role in the multiple livelihood strategies, food security, of poor and marginalised fishery dependent communities around the world. Sector specific, science based, technicist and centralistic management approaches have not been successful in achieving sustainable and equitable utilization resulting in degradation of natural resources in most rural areas and thus jeopardizing sustainable rural livelihoods and long-term economic development. In recent years there has been increased realization and emphasis on holistic and people-centred approaches to management and governance of natural resources. This comes under the rubric of "Ecosystem Approach to Management". This emerging emphasis is based on two concerns, which are sometimes in tension with each other - environmentalist or conservationist concerns over resource degradation, the loss of biodiversity and implicitly loss of rent to society; and 'people-first' concerns against protectionist (conservation oriented) thinking that gives primacy to conservation of natural resources over poverty and livelihoods.

Within this context, there is a need to revalue ecosystems that accounts for nature's role in people's economic and social well-being. Currently, there is greater emphasis placed on the environment due to resource consumption, habitat destruction, and waste production, resulting in environmental degradation that affects us all, but disproportionately impacts the world's poor or vulnerable. The livelihoods of large groups of people are being threatened by extreme economic stresses caused by migration from rural areas to urban centers, and increasing unemployment and underemployment globally.

Both social and natural sciences need to find new ways of adapting and integrating knowledge systems to address the complex, diverse and dynamic nature of the challenges facing poor and vulnerable fishery dependent communities. Crosscutting methodologies such as action research and trandisciplinary research are some examples that consider perspectives from both social and natural sciences'.

Institute for Poverty, Land and Agrarian Studies, University of Western Cape, South Africa

Presenting author: misaacs@uwc.ac.za

## SOCIO-ECONOMIC IMPACTS OF ARTIFICIAL REEFS ON THE SMALL SCALE FISHERS IN PENINSULAR MALAYSIA

Gazi Md. Nurul Islam, Kusairi Mohd Noh, Shaufique Fahmi Sidique, Aswani Farhana Mohd Noh

This paper investigates socio-economic benefits of artificial reefs (ARs) on the artisanal fishers in Terengganu - east coast of Peninsular Malaysia. A massive ARs programme has been implemented by the government over the past three decades in Malaysia. Various structures and designs of ARs have been deployed in the inshore sea beds of Terengganu to protect fisheries habitat from trawlers and to improve livelihoods of artisanal fishers. The data for this study was obtained from face-to-face interviews of 300 artisanal fishers selected from three districts; *Besut*, *Setiu* and *Terengganu* using a structured questionnaire.

Our findings indicate that catches vary significantly between the districts with density of AR structure, vessel types and gear use. The inboard powered vessels derive a significantly higher catch compared to outboard powered vessels. Fisher with small boats operate trip in the day while the inboard powered vessels operate fishing both in the day and night.

The outboard powered vessels largely operated fishing around ARs area except in Setiu where about half of the respondents have operated fishing in the non-ARs area. However, the fishers in Setiu have derived higher catch but spent more time searching for alternative fishing spots.

The study reveals that ARs have the potential to contribute incomes of fishers, but the fisheries in this area are under severe stress. A clear harvesting rules and access rights are needed to establish to control overfishing and resource degradation in marine waters in Malaysia.

Keywords: Artificial reefs; Small scale fisheries; Socio-economics; Production enhancement

Institute of Agricultural and Food Policy Studies, Universiti Putra Malaysia

Presenting author: gazinurul236@gmail.com

## SHOULD CLIMATE ENGINEERING BE CONSIDERED TO DEAL WITH CLIMATE CHANGE? AN EARTH SYSTEM MODEL EVALUATION OF MULTIPLE CLIMATE ENGINEERING APPROACHES

David P. Keller, Yuming Feng, and Andreas Oschlies

A number of climate engineering ideas have been proposed to deal with global climate change. The proposed methods either treat the causes or the symptoms of climate change through enhance carbon sequestration or the management of incoming solar radiation. Currently, the effectiveness of these methods and their secondary effects, which have the potential to cause catastrophic damage, are poorly understood. Although climate engineering is a controversial subject, evaluating the proposed methods is important because artificial manipulation of the climate may be necessary or desired by society at some time in the future and thus, the benefits and risks need to be quantified. Furthermore, since the costs of some methods are low enough that private entities or individual governments could implement them without a full global consensus, having a thorough understanding of them is necessary to prevent potentially dangerous actions. We use an Earth system model, which can identify not only local but also global feedback effects, to evaluate a number of climate engineering methods that are either ocean-based or will have a strong impact on the oceans. The methods include ocean fertilization, $CO_2$ sequestering ocean pipes, large-scale afforestation, enhanced chemical weathering, and solar radiation management. Although these methods have been studied individually before, their effectiveness and risks, relative to one another, have not been evaluated with one model as we have done. 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.

Helmholtz-Zentrum für Ozeanforschung Kiel (GEOMAR), Biogeochemical Modelling
Düsternbrooker Weg 20, 24105 Kiel - Germany

Presenting author: dkeller@geomar.de

## EXPLORING HUMAN-ENVIRONMENTAL INTERACTIONS IN SMALL-SCALE FISHERIES: IMPLICATIONS FOR MANAGING TOWARD SUSTAINABILITY

John N. (Jack) Kittinger

Despite general recognition of the human role in the plight of the ocean, the vast majority of research focuses on the ecological rather than the human dimensions of marine ecosystems, limiting our understanding of social relationships with these environments and potential solutions for managing toward sustainability. General frameworks for human-environmental relationships for a variety of systems have been advanced, but ocean-specific approaches are needed to develop a more nuanced view of social-ecological interactions for specific contexts and resource systems and at specific scales (e.g., community, national, regional). Here, I present a human dimensions framework that explores the linkages between social dimensions of small-scale fisheries ecosystems and environmental outcomes. Key features of this human dimensions framework include reciprocity between social and ecological systems, proximate and underlying dimensions, and the directionality of key relationships and feedback loops. Drawing on my own research in coral reef fisheries, I will present empirical information on how societies both impact marine ecosystems and benefit from the ecological goods and services that these environments provide. I will conclude by discussing how human dimensions research can help manage toward more sustainable outcomes, drawing on my own experience in participatory resource assessments and other examples from around the world.

Center for Ocean Solutions, Stanford University, Woods Institute for the Environment, 99 Pacific Street, Suite 555E, Monterey, CA 93940 USA

Presenting author: jkittinger@gmail.com

## LOCAL ADAPTATION AND MITIGATION MEASURES FOR THE GLOBAL CHANGE VULNERABILITY: A CASE STUDY OF ANDHRA PRADESH, INDIA

Shailendra Kumar Mandal and Kamini Sinha

The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report (2007) showed that the climate has changed and further change is expected. Warming of the climate is now evident from observations of increases in global average surface and ocean temperatures, widespread melting of snow and ice and rising global average sea level.

Altered frequencies and intensities of extreme weather, combined with sea level rise, are expected to have mostly adverse effects on natural and human systems. A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to global change. Adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies. Coastal communities in Andhra Pradesh are highly vulnerable to global change impacts, mainly because of three reasons, Resource dependency, High exposure and Limited adaptive capacity.

Therefore coastal communities are particularly vulnerable to global change impacts, as they have the most exposure to these risks but only limited adaptive capacity.

Addressing the diverse needs of coastal dwellings and considering the reducing the vulnerabilities to global change by interlinking adaptation and mitigation and disaster. Both, adaptation and mitigation are needed to cope with global change.

The Local adaptation and mitigation is a amalgam paper that includes background information and theory on global change, as well as results. It focuses on combining bottom-up and top-down approaches by strengthening communities' capacities to communicate their needs and priorities to decision-makers while also working with local governments to promote participatory planning process.

Department of Architecture, National Institute of Technology Patna, Patna, 800005, Bihar, India.

Presenting author: vastumandala@yahoo.com

## BUILDING NON-LINEAR SCENARIOS FOR MARINE FUTURES

Laurence Mee

The future of the marine environment is intimately connected to human lifestyles and the future social, political and macroeconomic pathway that humanity will choose. In 2004, we began a study of scenarios for all of Europe's seas involving specialists from 16 countries using a social ecological systems approach. We examined four plausible but extreme future scenarios derived from a grid of attitudes to governance and values and termed 'National Enterprise', 'Local Responsibility', Global Community', and 'World Markets'. This was compared with a baseline of projections including the OECD's economic forecasts. The approach was similar to the SRES scenarios used by the IPCC and, coupled with our causality studies, was a useful way of examining policy choices. The main difficulty arose when the 'credit crunch' took many economic forecasters by surprise and the baseline proved to be hugely overoptimistic. As part of the UK Natural Environmental Research Council's 'Valuing Nature Networks' programme, we have revisited the linear thinking that underpins many scenario studies and devised a way to 'shock' them with major economic. Political, physical, and ecological events could alter future pathways and have huge implications for the future of our seas. Future scenarios are constructed through informed focus groups with specialists and stakeholders employing rich pictures and then 'shocked' with carefully conceived major events. This is providing insights into system resilience and ecosystem service provision that have not been available previously.

Scottish Marine Institute, Scottish Association for Marine Science, Dunbeg, Oban, Argyll PA37 1QA, United Kingdom

Presenting author: laurence.mee@sams.ac.uk

## LIVELIHOOD STRATEGIES AND ACCESS TO BASIC SERVICES OF FISHERS IN POST CONFLICT NORTH AND EAST OF SRI LANKA

Mohammed Munas

Centre for Poverty Analysis is undertaking together with the Overseas Development Institute a survey of fisher communities in conflict affected areas of the country, focusing on the Districts of Mannar and Jaffna (Northern Province) and Trincomalee (Eastern Province). The survey looks at issues related to livelihood, basic services and social protection amongst the surveyed population. The survey would cover a total of 1377 households in the three Districts and also include households that engage in other professions for comparison purposes. The survey is presently underway and is expected to be completed in early November 2012.

A pilot survey undertaken during July 2012 to test the questionnaire and sample selection method, using fifty in the Trincomalee District in the east coast of Sri Lanka. The larger focus of the survey is on fisher families engaged in near shore fishing. The analysis of the pilot data highlighted a number of aspects about the fisher households, which included:

- That both men and women are involved in fishing activities
- About a half of the households have their houses on land they own, a third live in land they claim to own but have no deeds
- Whilst the houses of all households are of permanent structure one of the issues they seem to be having is in relation to toilets
- In terms of household assets, the non-fisher households report better levels of assets and majority of the fisher households have mobile phone, which is an important asset for their livelihood
- They start early on the vocation, consequently, the educational attainment of fisher folk is low, with just over a third reporting over 10 years of education
- The surveyed population reported intermediary buyers paying little, resource depletion and lack of fishing equipment as the main issues faced by them.
- There is not much difference between fisher households and non-fisher households in terms of those who are in debt. The fisher families report largely borrowing from the bank (pawning gold/ jewellery) and from the employer and most report that they borrowed for improving their livelihoods, whilst the balance borrowings were on account health and education related expenses. In addition shocks such as drought, floods and/or crop/ livestock diseases also resulted in them having to employ coping strategies ranging from selling assets, use savings, turning to friends and relatives and also borrowing money, indicating the vulnerability of these families.
- The community as a whole indicates that the larger issue that they face is in relation to water and health related services. They are also aware of the process through which they can obtain redressal and they have obtained relief for these issues. Community consultation is also high in relation to water. The issues, however remain unresolved in relation to livelihoods, though the people have complained to variety of actors.

The fuller survey will also cover issue related to displacement, supplementary income sources, type of fish caught, food security / diversity, social protection, support services from government/ donors/ non-governmental organisations and participation in governance. The presentation would thus cover these areas too.

Centre for Poverty Analysis (CEPA), Colombo, Sri Lanka

Presenting author: munas@cepa.lk

## REGIME SHIFTS IN COASTAL-MARINE SYSTEMS AND THE IMPLICATIONS FOR GOVERNANCE

Prateep Kumar Nayak and Derek Armitage

The growing potential for regime shifts in coastal-marine social-ecological systems - large, persistent and often unexpected changes in the structure and function of these systems with often significant implications for ecosystem services and human vulnerability – poses a profound challenge for governance and policy. For example, the identification of vulnerabilities (social, economic) is particularly difficult under conditions of rapid change, and in situations where thresholds in key system attributes (availability of fish, water quality) are being crossed at multiple spatial and temporal scales. Drawing on experiences from two coastal lagoon systems in India and Vietnam, we examine how approaches to governance must identify, acknowledge and navigate impending thresholds before they are crossed, and address the often undesirable consequences of regime shifts when they do occur. In this regard, we use a resilience lens to identify linked social-ecological variables and key indicators associated with potential threshold changes and regime shifts in these two lagoon systems. In particular, our analysis highlights the importance of socially and culturally-defined thresholds, in addition to ecologically defined thresholds, to provide an alternate way of conceiving change in complex systems. Such an approach is useful to recognize vulnerabilities of social-ecological systems to environmental change across multiple scales, and to help evaluate adaptive capacities of the system to navigate through such changes. Improved understandings of thresholds and regime shifts may help to identify key governance strategies and policy interventions that can empower societies to deal with undesirable consequences of coastal-marine environmental change. Conversely, better governance strategies may increase our ability to identify early signals of approaching shifts in social-ecological systems and respond before critical thresholds are crossed. We conclude with some reflections on the implications of threshold changes and regime shifts for human-environment interactions as a key indicator of governance and sustainability.

Faculty of Environment, University of Waterloo, 200 University Avenue West, Waterloo, ON, Canada, N2L 3G1

Presenting author: pnayak@uwaterloo.ca

## WORKING THROUGH COMPLEXITY: A TYPOLOGY FOR STRENGTHENING COASTAL GOVERNANCE IN THE CONTEXT OF CLIMATE CHANGE

Heidi Schuttenberg

The presence of effective governance systems strengthens the adaptive capacity of communities around the world to respond to global change. Governance systems are more effective when they are congruent with the political, socio-cultural, and ecological contexts in which they must operate. Understanding the relationship between effective governance arrangements and the complex systems in which they operate requires analytical approaches that can identify patterns in these relationships. The current study adapted a method from Organizational Theory to create a typology of approaches to coastal governance. The typology simplifies the complexity of these socio-ecological systems and identifies key issues that improved the fit between governance arrangements and contextual circumstances. By working with primary data from 60 projects across four countries in southeast Asia, we identified five dominant approaches for strengthening coastal governance and the underlying contextual conditions that were essential to the success of each approach. The results allow us to better forecast what types of coastal governance arrangements can be effective in diverse socio-ecological contexts, as well as providing a tool for guiding efforts to strengthen coastal governance and build adaptive capacity in areas particularly vulnerable to climate change.

University of Aberdeen, Sunnyside Steading, AB125YA Aberdeen, United Kingdom

Presenting author: heidi.schuttenberg@gmail.com

## CLIMATE CHANGE SCENARIOS AND THE ANCHOVY FISHERY IN NORTHERN CHILE

Eleuterio Yáñez[1], María Ángela Barbieri[1,2], Francisco Plaza[1,2] and Claudio Silva[1,3]

The Eastern South Pacific presents the Humboldt Current System, one of the most productive upwelling zones of the planet, especially of small pelagic fish such as anchovy (*Engraulis ringens*). This ecosystem is characterized by high biodiversity and production of forage fish for predators, seabirds and mammals. Moreover, estimates of forecast models represent Chile intensified winds, reduced rainfall and changes in sea surface temperatures produced by Climate Change. While species such as anchovy in northern Chile have limited distribution influenced by coastal winds, sea surface temperature and thermocline among other indicators. Then, the addition of yearly, interannual (El Niño, La Niña), interdecadal (regime shifs) fluctuations and the effects of climate change would produce environmental changes affecting the abundance and distribution of this important resource for Chile and particularly for Peru.

In this paper we develop Artificial Neural Network (ANN) models to forecast anchovy catches in northern Chile, through the integration of environmental and fishing variables. Then, these variables are simulated using climate change scenarios proposed by the Intergovernmental Panel on Climate Change (IPCC) and incorporated in the ANN models in order to estimate anchovy catches in response to various climate change scenarios. This represents a valuable tool for taking adaptation and mitigation actions, considering that in Chile over 90% of small pelagic species are used for fishmeal production that goes preferentially to the production of land animals (including pigs and birds) and aquaculture production (such as salmon and trout). The latter implies that climate change would not only directly affecting fisheries, but also indirectly in the production of other species of great impact on food security.

[1]Escuela de Ciencias del Mar, Facultad de Recursos Naturales, Pontificia Universidad Católica de Valparaíso. Casilla 1020, Valparaíso, Chile

[2]Instituto de Fomento Pesquero. Blanco 839, Valparaíso, Chile

[3]Centro Andaluz de Ciencia y Tecnología Marina (CACYT-MAR), Universidad de Cádiz. Polígono Río San Pedro s/n, 11510 Puerto Real, Cádiz, Spain

Presenting author: eyanez@ucv.cl

## PARTICIPANTS

**Alam, Lubna**
National University of Malaysia
LESTARI
Bangi 43600, Malaysia
lubna_762120@yahoo.com

**Angel, Dror**
University of Haifa
Mt Carmel
Haifa 31905, Israel
adror@research.haifa.ac.il

**Arenas Fuentes, Virgilio**
Universidad de Veracruz
Vera Cruz 94294, Mexico
varenas@uv.mx

**Avril, Bernard**
IMBER International Project Office
Institute of Marine Research
Bergen, Norway
Bernard.avril@imr.no

**Azam, Farooq**
Scripps Institution of Oceanography, UCSD
La Jolla CA 92093
USA
fazam@ucsd.edu

**Badesab, Shahin**
National Institute of Oceanography,
Panjim, Goa 403004
India
sbadesab@nio.org

**Baltar, Federico**
Linnaeus University
Kalmar 39182, Sweden
federico.baltar@lnu.se

**Barbieri, Maria-Angela**
Instituto de Fomento Pesquero
Blanco 839, Valparaiso, 1340000
Chile
angela.barbieri@ifop.cl

**Bardhan, Pratirupa**
COD, National Institute of Oceanography
Dona Paula, Goa 403004
India
pratirupabardhan@gmail.com

**Bhavya, PS**
Physical Research Laboratory, GSDN
Ahmedabad 380009
India
bhavya@prl.res.in

**Breitburg, Denise**
Smithsonian Environmental Research Center
Edgewater, MD 20676
USA
breitburgd@si.edu

**Branton, Bob**
Ocean Tracking Network (OTN)
Dalhousie University
Halifax, Canada
rmbranto@dal.ca

**Bundy, Alida**
DFO
Halifax HRM B2Y 4A2
Canada
alida.bundy@mar.dfo-mpo.gc.ca

**Burkill, Peter**
Plymouth University
Plymouth PL4 8AA
UK
peter.burkill@plymouth.ac.uk

**Caballero-Alfonso, Angela**
Lund University
Lund S-223 62
Sweden
Angela.Caballero-Alfonso@geol.lu.se

**Campos, Maria Rebecca**
University of the Philippines Open University
Los Banos 4031
Philippines
cmaribec@yahoo.com

**Cannaby, Heather**
Institute of Marine Sciences
Middle East Technical University
Erdemli (Mersin) 33731
Turkey
heather.cannaby@ims.metu.edu.tr

**Chandler, Cynthia**
Woods Hole Oceanographic Institution
Woods Hole MA 2543
USA
cchandler@whoi.edu

**Chuenpagdee, Ratana**
Memorial University of Newfoundland
St. John's Newfoundland A1B3X9
Canada
ratanac@mun.ca

**Cloern, James**
US Geological Survey
Menlo Park CA 94560
USA
jecloern@usgs.gov

**Cooley, Sarah**
Woods Hole Oceanographic Institution
Woods Hole MA 2649
USA
scooley@whoi.edu

**Currie, Bronwen**
Swakopmund
Namibia
bcurrie@mfmr.gov.na

**Dang, Hongyue**
China University of Petroleum
Qingdao, Shandong 266580
China
DangHY20042000@yahoo.com.cn

**de Sherbinin, Alex**
CIESIN
Columbia University
Palisade, NY
USA
adesherbinin@ciesin.columbia.edu

**Deutsch, Curtis**
University of California, Los Angeles
Los Angeles CA 90024
USA
cdeutsch@atmos.ucla.edu

**Emeis, Kay-Christian**
Helmholtz-Center Geesthacht
Geesthacht 21502
Germany
kay.emeis@hzg.de

**Färber Lorda, Jaime**
CICESE
Ensenada 22860, Baja California
Mexico
jfarber@cicese.mx

**Felden, Janine**
Universität Bremen
Bremen
Germany
jfelden@marum.de

**Flynn, Kevin**
Swansea University
Swansea
UK
k.j.flynn@swansea.ac.uk

**Gauns, Mangesh**
National Institute of Oceanography
Dona Paula, Panaji 403 004
India
gmangesh@nio.org

**Gazihan Akoglu, Ayse**
Institute of Marine Sciences
Middle East Technical University
Mersin 33731
Turkey
aysegazihan@gmail.com

**Giani Michele, Rudjer**
Boskovic Institute
Trieste
Italy
mgiani@inogs.it

**Glaeser, Bernhard**
German Society for Human Ecology (DGH)
Berlin 14169
Germany
bernhardglaeser@gmail.com

**Glaser, Marion**
Centre for Tropical Marine Ecology
Bremen 28359
Germany
marion.glaser@zmt-bremen.de

**Glavovic, Bruce**
Massey University
Palmerston North 4442
New Zealand
b.glavovic@massey.ac.nz

**Goffart, Anne**
University of Liege
Liege 4000
Belgium
a.goffart@ulg.ac.be

**Goswami, Prasun**
Madras University
Chennai 600 025
India
prasun.goswami@gmail.com

**Gupta, G.V.M.**
Centre for Marine Living Resources & Ecology
Kakkanad, Cochin, Kerala 682037
India
gvmgupta@gmail.com

**Hall. Julie**
National Institute of Water & Atmospheric Research
Wellington
New Zealand
J.hall@niwa.co.nz

**Hardman-Mountford, Nick**
CSIRO
Floreat WA 6913
Australia
nick.hardman-mountford@csiro.au

**Herndl, Gerhard**
University of Vienna
1090 Vienna
Austria
gerhard.herndl@univie.ac.at

**Hofmann, Eileen**
Old Dominion University
Norfolk, VA 23508
USA
hofmann@ccpo.odu.edu

**Hu, Liuming**
IMBER Regional Project Office
East China Normal University
Shanghai 200062
China
liumingh@sklec.ecnu.edu.cn

**Isaacs, Moenieba**
University of Western Cape
Bellville, Western Cape 7935
South Africa
misaacs@uwc.ac.za

**Islam, Gazi**
Institute of Agricultural and Food Policy Studies
Serdang 43400
Malaysia
gazinurul236@gmail.com

**Jang, Chan Joo**
Korea Institute of Ocean Science & Technology
Ansan
South Korea
cjjang@kordi.re.kr

**Jayakumar, Amal**
Princeton University
Princeton 08544
USA
ajayakum@princeton.edu

**Jiang, Xuexia**
Xiamen University
Xiamen 361005
China
jiangxuexia@xmu.edu.cn

**Jiao, Nianzhi**
Xiamen University
Xiamen 361005
China
jiao@xmu.edu.cn

**Keller, David**
GEOMAR
24105 Kiel
Germany
dkeller@geomar.de

**Kirchman, David**
University of Delaware
Lewes DE 19958
USA
kirchman@udel.edu

**Kittinger, John**
Stanford University
Monterey CA 93940
USA
jkittinger@stanford.edu

**Koch, Boris**
AWI for Polar and Marine Research
Bremerhaven 27570
Germany
Boris.Koch@awi.de

**Kremer, Hartwig**
LOICZ International Project Office
Helmholtz-Zentrumn Geesthacht
Geesthacht 21502
Germany
hartwig.kremer@loicz.org

**Kurien, Siby**
India National Institute of Oceanography
Dona Paula, Goa 403004
India
siby@nio.org

**Lachkar, Zouhair**
ETH Zurich
Zurich
Switzerland
zouhair.lachkar@env.ethz.ch

**Legendre, Louis**
Pierre & Marie Curie University Paris 6
06230 Villefranche-sur-Mer
France
legendre@obs-vlfr.fr

**Levin, Lisa**
University of California
La Jolla CA 92093-0218
USA
llevin@ucsd.edu

**Li, Chao**
China University of Geosciences
Wuhan 430074
China
ucrchaoli@gmail.com

**Li, Qian**
Xiamen University
Fujian 361005
China
liqian00@xmu.edu.cn

**Limburg, Karin**
State University of NY
Syracuse NY 13210
USA
klimburg@esf.edu

**Liu, Kon-Kee**
National Central University
Jungli, Taoyuan County 32001
Taiwan
kkliu@ncu.edu.tw

**Lorenzoni, Laura**
University of South Florida
Saint Petersburg, Florida 33701
USA
laural@mail.usf.edu

**Maddison, Lisa**
IMBER International Project Office
Institute of Marine Research
Bergen, Norway
Lisa.Maddison@imr.no

**Mandal, Shailendra**
National Institute of Technology
Patna
India
vastumandala@yahoo.com

**Manohar, Cathrine**
National Institute of Oceanography
Goa
India
cathrine@nio.org

**McManus, Liana**
Self-employed
Pembroke Pines, FL 33028
USA
lmcmanus57@gmail.com

**Mee, Laurence**
Scottish Marine Institute
Scottish Association for Marine Science
Oban, Argyll PA37 1QA
UK
laurence.mee@sams.ac.uk

**Miquel Juan, Carlos**
International Atomic Energy Agency
Monaco MC 98000
Monaco
j.c.miquel@iaea.org

**Mitra, Aditee**
Swansea University
Swansea
UK
a.mitra@swansea.ac.uk

**Montes, Enrique**
University of South Florida
St Petersburg FL 33701
USA
emontesh@mail.usf.edu

**Munas, Mohammed**
Centre for Poverty Analysis (CEPA)
Colombo
Sri Lanka
munas@cepa.lk

**Naqvi, Wajih**
India National Institute of Oceanography
Dona Paula, Goa 403004
India
naqvi@nio.org

**Nayak, Prateep**
University of Waterloo
Waterloo, Ontario N2L 3G1
Canada
pnayak@uwaterloo.ca

**Neuer, Susanne**
Arizona State University
Tempe 85287
USA
susanne.neuer@asu.edu

**Nurdjaman, Susanna**
Bandung Institute of Technology
Bandung 40132
Indonesia
susanna@fitb.itb.ac.id

**O'Brien, Todd**
NOAA – National Marine Fisheries Service
Silverspring, MD
USA
Todd.OBrien@noaa.gov

**Oh, Yuri**
Korea Institute of Ocean Science & Technology
Sangnok-gu, Ansan 426-744
South Korea
ourmail@kiost.ac

**Pesant, Stéphane**
PANGAEA Data Publisher for Earth & Environmental Sciences
MARUM / Universität Bremen
Germany
spesant@marum.de

**Pienta, Amy**
Population Studies Center
University of Michigan
Ann Arbor, MI
USA
apienta@umich.edu

**Prakash, Satya**
National Centre for Ocean Information Services
Hyderabad 500090
India
satyap@incois.gov.in

**Rabouille, Christophe**
CEA-CNRS-UVSQ
Gif sur Yvette 91190
France
rabouill@lsce.ipsl.fr

**Ragueneau, Olivier**
CNRS
Brest
France
Olivier.Ragueneau@univ-brest.fr

**Ramesh, Ramachandran**
National Centre for Sustainable Coastal Management
Chennai 600025
India
rramesh_au@yahoo.com

**Ren, Rui**
Xia Men University
Xia Men 361005
China
renruixm@gmail.com

**Robinson, Carol**
University of East Anglia
School of Environmental Sciences
Norwich, NR4 7TJ, UK
carol.robinson@uea.ac.uk

**Romanou, Anastasia**
Columbia University and NASA-GISS
New York NY 10027
USA
ar2235@columbia.edu

**Sarin, Manmohan**
Physical Research Laboratory, Navrangpura
Ahmedabad 380009
India
sarin@prl.res.in

**Sarkar, Amit**
National Institute of Oceanography
Dona Paula, Goa 403004
India
amit.sarkar@nio.org

**Sasai, Yoshikazu**
JAMSTEC
Yokohama
Japan
ysasai@jamstec.go.jp

**Schuttenberg, Heidi**
University of Aberdeen
Aberdeen AB125YA
UK
heidi.schuttenberg@gmail.com

**Shenoy, Damodar**
National Institute of Oceanography
Dona Paula, Panaji, Goa 403402
India
dmshenoy@nio.org

**Smetacek, Victor**
Alfred Wegener Institute for Poalr and Marine Research
Bremerhaven 27570
Germany
Victor.Smetacek@awi.de

**Swaney, Dennis**
Cornell University
Ithaca, New York 14853
USA
dps1@cornell.edu

**Tang, Kai**
Xiamen University
Xiamen 361005
China
tangkai@xmu.edu.cn

**Tedesco, Kathy**
UCAR/NASA
Washington DC 20546
USA
ktedescoparis@gmail.com

**Thomas, Helmuth**
Dalhousie University
Halifax B3H 4R2
Canada
helmuth.thomas@dal.ca

**Vidya, P.J.**
National Institute of Oceanography,
Dona Paula, Goa-403004
India
pjvidya@gmail.com

**Wang, Xiaoxue**
South China Sea Institute of Oceanology, CAS
Guangzhou 510301
China
xxwang@scsio.ac.cn

**Wassmann, Paul**
University of Tromsø, Breivika
Tromsø N-9037
Norway
paulw@nfh.uit.no

**Wishner, Karen**
University of Rhode Island
Narragansett RI 2882
USA
kwishner@gso.uri.edu

**Xia, Meng**
University of Maryland Eastern Shore
Princess Anne MD 21601
USA
mxia@umes.edu

**Yañez, Eleuterio**
Pontificia Universidad Catolica de Valparaiso
Valparaìso 2360007
Chile
eyanez@ucv.cl

**Yumruktepe, Veli (Çağlar)**
Institute of Marine Sciences
Middle East Technical University
Mersin 33731, Turkey
caglar@ims.metu.edu.tr

**Zhang, Rui**
Xiamen University
Xiamen 361005
China
ruizhang@xmu.edu.cn

**Zhang, Zilian**
Xiamen University
Xiamen 361005
China
zhangzilian@xmu.edu.cn

**Zuo, Fang**
IMBER Regional Project Office
East China Normal University
Shanghai 200062
China
Zuo.fang.ecnu@gmail.com


**Produced by:**
**IMBER International Project Office**
**IMBER Regional Project Office**
**(January 2013)**

Poster and cover design by: Sébastien Hervé
Email: contact@sebastien-herve.com Website: www.sebastien-herve.com

**Contact: imbizo@imr.no** **Website: www.imber.info**