APN CAPaBLE

- Making a Difference –

Scientific Capacity Building & Enhancement for Sustainable Development in Developing Countries

Final Report

Project Reference Number: CBA2014-11NSY(B&ES)-Zhang

IMBER ClimEco4 Summer School – Delineating the Issues of Climate Change and Impacts to Marine Ecosystems: Bridging the Gap between Research, Assessment, Policy and Management

The following collaborators worked on this project:

1. Alida Bundy, Fisheries and Oceans Canada, Canada, alida.bundy@dfo-mpo.gc.ca
2. Jiahua Cheng, East China Sea Fisheries Research Institute, China, ziyuan@sh163.net
3. Laura David, University of the Philippines Marine Science Institute, The Philippines, ldavid@upmsi.ph
4. Elizabeth Fulton, Commonwealth Scientific and Industrial Research Organisation, Australia, beth.fulton@csiro.au
5. Eric Galbraith, McGill University, Canada, eric.galbraith@mcgill.ca
6. Scott Large, NOAA, National Marine Fisheries Service, USA, Scott.large@noaa.gov
7. Stéphane Pesant, Universität Bremen, Germany, spesant@marum.de
8. Yongsong Qiu, South China Sea Fisheries Research Institute, China, qys@scsfri.ac.cn
9. Keith Sainsbury, University of Tasmania, Australia, ksainsbury@netspace.net.au
10. Rashid Sumaila, Fisheries Centre, University of British Columbia, Canada, r.sumaila@fisheries.ubc.ca
11. Ingrid van Putten, Commonwealth Scientific and Industrial Research Organisation, Australia, Ingrid.Vanputten@csiro.au

IMBER

EAST CHINA NORMAL UNIVERSITY

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

The Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project (http://www.imber.info/) is a multi-disciplinary, international project that seeks to identify the mechanisms by which global change and anthropogenic forcing influence marine biogeochemical cycles and marine food webs and how these, in turn influence marine ecosystems and human society. To this end, IMBER focuses on fostering research at the interface of natural and human systems.

The ClimEco4 summer school on "Delineating the issues of climate change and impacts to marine ecosystems: Bridging the gap between research, assessment, policy and management", was held in August 2014 at the East China Normal University (ECNU) in Shanghai, China. It provided an opportunity to contribute to the community of inter-disciplinary marine researchers who work at the interface of natural and human systems; a community that is only now starting to develop.

ClimEco4 focused on indicators for evaluating marine ecosystems, focusing on their definition, construction and use, and how to combine them to inform policy and decision-making. Lectures included a climate change primer, general information on databases, statistical data analysis for indicators, using indicators with ecosystem and socio-economic models, and criteria and use of indicators for informing marine management and policy. Each afternoon, practical sessions with example databases, indicators, and models provided applications of the concepts covered in the lectures.

Keywords

IMBER, summer school, indicators, marine ecosystems

Objectives

The main objectives of the project were:

1. To contribute to building the capacity of the IMBER and international marine science community, that works on global change issues at the interface of human and marine systems.

2. To make more new researchers aware of, and provide them with, the techniques and methods to address and evaluate climate change impacts on marine ecosystems, and how to transform data into usable products, tools or advice.

3. To contribute to the improvement of information and knowledge transfer in global change research to more effectively manage the impacts and consequences to human and marine systems.

Amount received and number years supported

The Grant awarded to this project was: US$ 35,000 for Year 1

Activity undertaken

Applications to attend the ClimEco4 summer school were sent to the IMBER International Project Office and the participants were selected based on their research interests, as well as to provide geographic distribution and gender balance.

ClimEco4 was held at the East China Normal University in Shanghai, China from 4-9 August 2014. The summer school convened 10 lecturers, including marine biologists, oceanographers and fisheries management specialists, ecologists, ecosystem modellers, and social scientists and bioeconomists. Because of the hands-on nature of the training, only 60 participants were selected, including MSc and PhD students, postdocs, and early career researchers. They too represented a variety of disciplines, and hailed from 26 countries across five continents. In the end 50 of the selected participants attended the summer school.

The course consisted of lectures each morning (which were live-streamed), hands-on exercises using different models and statistical techniques in the afternoons, and group projects that utilised these techniques and methods to analyse a data set comprising a socio-ecological system. Each participant presented a poster of their current research, and prizes were awarded for the best presentations.

Results

1. Twenty-four lectures were given by international experts with real-life case studies to illustrate how to use indicators to address climate change impacts on marine ecosystems.
2. Live-steamed lectures enabled those who were unable to attend to follow the lectures.
3. Participants were equipped with the ways to source, analyse and transform data into usable products, tools or advice.
4. The practical sessions provided the opportunity to apply techniques and methods that were presented during the lectures in real-world situations.
5. Through interactions with people involved with management, analysis, and reuse of ecological and socio-economic data with a focus on understanding the effects of climate change, participants expanded their international and interdisciplinary networks, and created opportunities for collaborations in the future.

Relevance to the APN Goals, Science Agenda and Policy Processes

The topic of the summer school - *Delineating the issues of Issues of Climate Change and Impacts to Marine Ecosystems: Bridging the Gap Between Research, Assessment, Policy and Management* - focused very much on research at the interface of natural and human systems. Participants learnt about indicators of climate change, climate impacts and marine ecosystem services, and their links to socio-economic indicators and policy information related to climate-ecosystem interactions. This of importance to IMBER, to contribute to developing a community of inter-disciplinary marine researchers who work at the interface of natural and human systems. This is directly relevant to APN's science agenda focus on "promoting research that improves understanding of the physical, biological and human dimension of change in the Earth System…". The focus is also aligned with the APN goal of "improving the scientific and technical capabilities of nations in the region". It also fit

well with the objectives of APN's CAPaBLE programme, to enhance capacity in developing countries to generate and share knowledge about climate change impacts, vulnerabilities, adaptation and mitigation, as well as of informed decision-making through the dissemination of the outcomes to policy-makers and other stakeholders.

Self evaluation

By all accounts the summer school was a great success and evaluations from the participants indicated that, in most respects, we achieved our goals.

We gathered an impressive group of international experts to deliver the summer school and the standard of the lectures was extremely high. Having the lecturers involved for the duration of the summer school worked very well. They were all very approachable and ensured an unintimidating atmosphere. That, and limiting the number of participants, ensured that everyone was given the opportunity to participate and interact, and that assistance and expert advice was always available during the practical sessions and group work. The lecturers also made an effort to network and interact with the students, which has resulted in some on-going collaborations.

The diversity of disciplines and cultural backgrounds made for interesting interactions in the group projects. However, the projects should perhaps have been more focused, some had a very broad scope.

Having students bring their own databases to work on did not work as well as we had hoped. The data "owner" tended to dominate during the group work, and in some cases, influenced the analysis process, because they had a specific outcome in mind.

The poster session was very successful. Each participant presented a poster on their research and these were evaluated by a group of lecturers who provided individual suggestions and comments. Students found the feedback extremely useful.

Potential for further work

Several participants arranged to work collaboratively with other participants, and in at least two cases, with one of the lecturers. All the students are given the opportunity to publish articles on their research or about their experiences at the IMBER summer school in the IMBER Update newsletters. We also run an article in each newsletter publication by one of the students, to enable them to show how the summer school has influenced their research or career paths (Suprenand P. 2015). IMBER holds a summer school every two years, so another will be held in 2016. Some students have attended more than one ClimEco summer school

Publications (please write the complete citation)

1. Maddison L., Van Putten I and Zuo F. 2015. Indicators to address climate change impacts on marine ecosystems. Past Global Changes Magazine 23(1): 33.
2. Suprenand P. Where are they now? June 2015 IMBER Update newsletter No. 28, pp.22.

3. Videos of all the ClimEco4 lectures on Youtube and Dailymotion. See: http://www.imber.info/index.php/Early-Career/IMBER-Summer-Schools/ClimEco4-August-2014-Shanghai-China/IMBER-ClimECO4-Lecture-Videos.
4. "IMBER ClimEco4 Summer School - Delineating the Issues of Climate Change and Impacts to Marine Ecosystems: Bridging the Gap between Research, Assessment, Policy and Management," APN E-Lib, http://www.apn-gcr.org/resources/items/show/1937.
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TECHNICAL REPORT

Preface

The ClimEco4 summer school continued IMBER's focus on fostering research at the interface of natural and human systems, bringing participants from different disciplines and regions to share their perspectives on the challenges that human and marine systems are facing under global change. As the marine environment is very complex, indicators can provide a practical and economical way to track the state of ecosystems. ClimEco4 was structured around lectures and activities focusing on indicators of climate change, climate impacts, and ecosystem services, and how these are linked to indicators for socio-economic and policy information in relation to climate-ecosystem interactions.

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1.0 Introduction

1.1 Background information

IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) is an international project, established by the International Geosphere-Biosphere Programme (IGBP) and the Scientific Committee on Oceanic Research (SCOR), to identify the effects of global change on the biogeochemistry and ecosystems of the oceans, and to better understand, and accurately predict, ocean responses to accelerating global change, and the consequent effects on the Earth System and human society.

During IMBER's first 10 years, the focus was on identifying the impacts of global change on biogeochemical-ecosystem interactions, ocean responses and how these impact human society. Now IMBER research is directed more towards integrated marine research for developing and implementing options within and across the natural and human sciences, and to communicate relevant information and knowledge needed by society to secure sustainable, productive and healthy oceans.

Consequently, the development and fostering of research capacity in integrated studies of biogeochemistry and end-to–end food webs, as well as socio-ecological aspects relating to the ocean and global change, is a priority for IMBER. Summer schools are an important capacity building activity for IMBER and the international marine science community. They are held every second year and provide training in techniques and methods in cutting-edge IMBER research for M.Sc. and Ph.D. students, and early career researchers (less than 10 years after Ph.D.). The summer schools aim to equip young researchers to work in interdisciplinary teams to address the complex issues facing marine ecosystems and the human societies that depend on them, in the context of climate change.

1.2 Scientific significance and objectives of this activity

The topic chosen for ClimEco4 - Delineating the issues of climate change and impacts to marine ecosystems: Bridging the gap between research, assessment, policy and management - was considered to be timely and important to contribute to a community of researchers who are aware of, and have the tools to address and evaluate climate change impacts on marine ecosystems and the consequences for management of these systems. The aim was to provide training that would enable them to source, analyse and transform data into usable products, tools or advice. ClimEco4 brought together those involved with management, analysis, and reuse of ecological and socio-economic data with a focus on understanding the effects of climate change on marine socio-ecological systems.

2.0 Methodology

In June 2013, about 14 months prior to the summer school, the IMBER International Project Office (IPO) put out a call to the IMBER science community, including previous summer school attendees and lecturers, asking for current, relevant topics for ClimEco4. At the same time, the ClimEco4 Organising Committee, comprising two co-conveners, the Chair of the IMBER Scientific Steering Committee, and IMBER Project Office staff, was established (see Appendix I). The Committee met

"virtually" on a regular basis to consider all the theme suggestions that were submitted. It was decided that a summer school dealing with the use of indicators for marine research and modelling would be beneficial. They then set about clarifying the course content (the initial programme structure) and required expertise.

Once the programme (see Appendix II) had been developed further, experts, where possible from the Asia-Pacific region, were identified and invited to lecture on specific topics. Including the conveners, there were 11 lecturers (see Appendix I). To ensure that the summer school was multidisciplinary, they included natural and social scientists, economists, data specialists, modellers and a marine management and policy advisor. All the lecturers committed to attending and being involved in all sessions, for the duration of the summer school. Unfortunately, due to work commitments, Dr. Jason Link and Dr. Xinji Jin who had been part of the original Organising Committee, found that they would not be able to attend the summer school and reluctantly withdrew, both from the Committee and as lecturers. They were replaced by Dr. Stéphane Pesant, a data integration specialist from Germany, and Drs. Jiahua Cheng and Yongsong Qiu, Marine fisheries specialists from China.

Regular web-based meetings with the Organising Committee and the lecturers ensured that the course content would cover all the necessary topics, and that lectures were coordinated, the order logical and that there was no repetition.

A poster, call for applications and other announcements about ClimEco4 were distributed via the extensive IMBER contact list and those of the sponsors and partner organisations. The IMBER website was used for advertising, registration, and later live-broadcasting of the lectures.

More than 180 applications to attend the summer school were. A selection committee (composed of the ClimEco4 conveners and three of the lecturers) used predesigned selection criteria to ensure that all the students had a basic level of understanding (e.g. statistics and modelling), geographic distribution, gender balance and disciplinary expertise. The number of participants selected was limited to 60. This group size proved to be optimal for student-lecturer interactions, interactive practical sessions and group projects at previous IMBER summer schools. Participants were provided with relevant literature as background reading to prepare for the summer school. Ultimately, about 50 participants attended the summer school.

Applicants were given the opportunity to bring their own data to work on during the practical sessions. Alternatively, they could use datasets that were provided. Those with their own data were asked to send a sample, so that the conveners could determine if it was appropriate for the planned exercises, and whether it needed to be augmented with other types of data.

Lectures were given each morning. Initial lectures provided overview and background information to familiarize everyone with the terminology, concepts and processes that would be discussed in subsequent, more-focused lectures.

The afternoons were devoted to practical sessions, where the concepts covered in the lectures were applied, and the participants were given the opportunity of working with databases, indicators and models. All the lecturers were available to provide assistance as required.

To encourage working in interdisciplinary teams, participants from different disciplines were assigned to groups (3-6 students) to conduct a group project. Modelling and statistical techniques and methods presented during the course were applied to real-world socio-ecological data, to provide an analysis the state of the system and possible management approaches and tradeoffs. The results from each group were presented on the final day, to a panel who provided feedback and suggestions.

All the participants were asked to bring a poster to showcase their research during a poster session that was held on the first evening. Half the participants presented their posters in the first session, and the other half during the second session. The posters remained on display for the duration of the summer school. Three lecturers evaluated the posters and provided individual feedback to the students, to help them improve their presentation techniques.

3.0 Results & Discussion

The Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project's goal is to better understand the interactions and linkages between biogeochemical cycles and food webs, including humans, with a view towards improving the predictive capacity for marine ecosystems increasingly affected by global change.

3.1 Capacity building

From the outset, IMBER recognised capacity building as a critical component to successfully addressing its goal, especially with regard to human-ocean interactions. Because of its standing as a well-established interdisciplinary marine science project, with an international network that includes experts from both the natural and social sciences, the project is in an excellent position to promote the education and training of students and early career researchers from around the world, including those from less-developed countries, in emerging cross-disciplinary and integrative marine science. IMBER summer schools are a particularly important capacity building activity and play a critical role in helping to develop a community of researchers who work at the interface of human and natural sciences. They are designed to provide training for M.Sc. and Ph.D. students and early career researchers, in techniques and methods used in cutting-edge IMBER science. Such training is either very limited, or not available at all, through traditional academic curricula. The summer schools focus on topics dealing with climate change, its impacts on marine ecosystems and the human populations that depend on them. This emphasis on human-natural science interactions make the ClimEco summer schools unique. They contribute to capacity building by supporting the development of a newly emerging community of researchers who work at the interface of natural and human systems. Table 1 provides an overview of the themes and topics covered by all the IMBER summer schools that have been convened thus far, and have provided training for more than 250 participants.

Table 1. Contribution of ClimEco summer schools to IMBER's scientific themes

Summer school	Title	Location and Date	Course content	IMBER Themes
ClimEco	Climate Driving of Ecosystem Change	Brest, France 21-24 April 2008	• Impacts of climate variability on the marine environment • Physical climate variability changes and their impact on the marine environment • Modelling aspects of the ocean and climate • Statistical analysis techniques and the link from climate to marine ecosystems	**Theme 1:** Key Interactions **Theme 2:** Sensitivity to Global Change
ClimECO$_2$	Oceans, Marine Ecosystems, and Society Facing Climate Change: A Multidisciplinary Approach	Brest, France 23-27 August 2010	• Climate, ocean circulation, biogeochemistry and marine ecosystems • Climate-driven changes in marine biodiversity and interactions among species • Impact of global change on marine resources and uses • Vulnerability and adaptation to climate change in the coastal zone • Communicating climate change: from information to action	**Theme 1:** Key Interactions **Theme 2:** Sensitivity to Global Change **Theme 3:** Feedbacks to the Earth System **Theme 4:** Responses of Society
ClimEco3	A View Towards Integrated Earth System Models: Human-Nature Interactions in the Marine World	Ankara, Turkey 23-28 July 2012	• Overview of Earth System and socio-economic models • Modelling low trophic level processes and human interactions	**Theme 1:** Key Interactions **Theme 4:** Responses of Society
ClimEco4	Delineating the Issues of Climate Change and Impacts to Marine Ecosystems: Bridging the Gap between Research, Assessment, Policy and Management	Shanghai, China 4-9 August 2014	• Overviews of climate change • General information on data bases • Data analysis methods for indicators • Criteria and use of indicators for informing management and policy	**Theme 2:** Sensitivity to Global Change **Theme 3:** Feedbacks to the Earth System **Theme 4:** Responses of Society

3.2 ClimEco4 aims

The ClimEco4 summer school was the fourth in the ClimEco series. It was held at East China Normal University (ECNU) in Shanghai, China from 4-9 August 2014. The IMBER community had identified using indicators to evaluate marine ecosystems, as a pertinent and timely subject for young researchers and students working on topics related to the oceans and climate change. Thus the theme chosen for ClimEco4 was "Delineating the issues of climate change and impacts to marine ecosystems and human societies: Bridging the gap between research, policy and management". Although considerable resources are invested in global environmental change research, as well as in the development of policy and management strategies for marine resources, there tends to be a disconnect in effectively transferring information and knowledge from one community to another, in terms of how to effect changes in the use and management of resources. ClimEco4 thus, aimed to impart learning about climate change pressures on marine systems, and how to analyze and model these using indicators. It is crucial, however, to be able to explain the results appropriately, to ensure that decision makers include marine systems research in their governance processes. Participants were therefore also presented with communication techniques to increase the chance of useful and meaningful outcomes.

Because of the complexity of the marine environment, particularly in the context of global change, indicators are often used to provide a practical and economical way to track the state and trends of social, economic and ecological systems. They provide an approach for characterising and combining information from the natural sciences and the human dimensions of policy and management, in a manner that is useful to both communities. ClimEco4 aimed, to teach participants how to source, analyse and transform data into indicators, that could then be used to assess the ecological state of a marine ecosystem, the environmental states and trends, benefits to society, and its long term ecosystem sustainability. The training included: how to select and construct indicators, how to use them in models, and ultimately how to combine them to be able to inform policy and decision-making.

In the interest of facilitating transdisciplinary training and research and contributing to a community that can address topics related to climate-ecosystem-human interactions, ClimEco4 brought together researchers involved with management, analysis and reuse of ecological, climate and socio-economic data.

3.3 The participants

IMBER summer schools aim to equip young researchers from both developed and developing countries to work in interdisciplinary teams to address global issues in coastal and marine systems. The call for applications for ClimEco4 was distributed widely to attract participants from a variety of disciplines in both the natural and social scientists. More than 180 applications were received for the 60 available places.

Predetermined criteria (Fig. 1) were used to ensure that the participants had a certain level of understanding of statistics and modelling, in order to benefit from the training. It was also deemed important that there should be gender and geographic balance, that different scientific disciplines

were represented, and that applicants from developing countries be given priority, in accordance with the CAPaBLE programme goals (see Fig. 2 for the geographic distribution and research status of the participants).

Fig. 1 Selection criteria used to ensure that ClimEco4 participants had an appropriate level of understanding and experience, and to ensure gender and geographic balance.

The ClimEco4 participants came 25 countries on five continents. These included: Australia, Bangladesh, Brazil, Canada, China, Fiji, Germany, Greece, India, Israel, Italy, Japan, Malaysia, Norway, The Philippines, Poland, Portugal, South Africa, South Korea, Spain, Sri Lanka, Sweden, Taiwan R.O.C., Ukraine and the USA. For a full list of the participants and their affiliated institutions and universities, please see Appendix III.

It must be stated that despite our best efforts to attract social scientists, the majority of participants were from natural science disciplines. However, there was a noticeable (if small) increase in the number of applications from social scientists compared with previous summer schools, so we take this as a positive sign that the summer school topics are becoming more interesting to social scientists, although at a slow pace. IMBER will continue to explore new ways of attracting them to future summer schools.

The IMBER Regional Project Office in Shanghai, China, used its extensive network to attract recruits from the Asia-Pacific region. This is the first IMBER summer school to have been held in Asia, and IMBER welcomed the opportunity of increasing the number participants from the region. Several local students from the East China Normal University, host of the IMBER Regional Project Office, were also invited to attend.

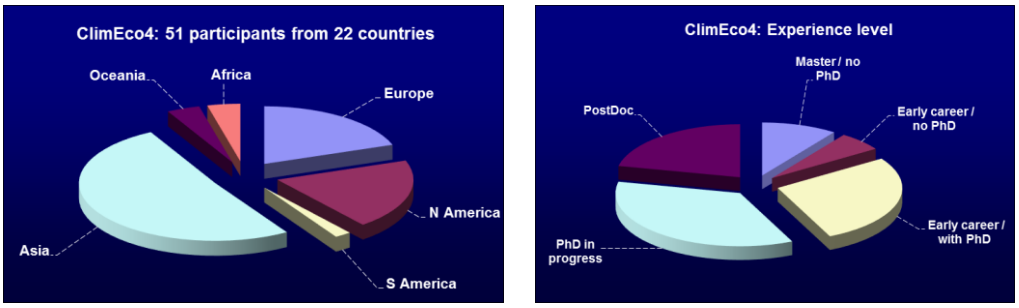

Fig. 2 Regional distribution (left) and status or experience level (right) of the ClimEco 4 summer school participants.

3.4 The lecturers

A team of 10 experts, drawn from the natural and social science communities, provided their perspectives and approaches to marine science by way of lectures, discussions, personal anecdotes and case studies, input during the practical sessions and also through their evaluation and feedback of the posters and group projects. Their knowledge about ways to bridge the barriers between disciplines is essential if we are to develop a community that can address topics related to climate-ecosystem-human interactions. Thus, in addition to providing expertise, the lecturers proved to be strong role models for participants with an interest in pursuing transdisciplinary research.

3.5 The course

The programme is given in Appendix III. Twenty-four lectures were given by the international experts described above. The lectures were live-streamed from the East China Normal University's live channel (http://live.ecnu.edu.cn). About 20 people followed the lectures from different parts of the world. Several were applicants who had not been selected, and at least three had been selected, but for various reasons were unable to attend. The lectures are now archived on the IMBER website (http://www.imber.info/index.php/Early-Career/IMBER-Summer-Schools/ClimEco4-August-2014-Shanghai-China/IMBER-ClimECO4-Lecture-Videos).

To bring everyone up to speed, the first set of lectures introduced relevant terminology and concepts. Then climate change issues and impacts on marine ecosystems from biophysical, socio-economic and governance perspectives were discussed. This was followed by a general overview of indicators; what they are and how and where they are used (Table 2). Next, the use of indicators to examine climate change and marine biogeochemistry at different time scales was outlined. Eric Galbraith from McGill University, Canada provided the paleo perspective and gave an entertaining depiction of the history of the Earth occurring within a single calendar year (viewed on YouTube at: https://www.youtube.com/watch?v=zlDm97EE5-o&list=PLdGczf8u6mldMPIqdLi6urVozqIpfO_jr&index=19.

The next set of lectures focused on modelling in the context of indicators, and acquiring, accessing, and analysing data including quality control and nonlinearity exploration, such as detecting "tipping

points" and developing decision criteria. Statistical techniques, data sharing, and approaches on publishing and reusing scientific data were also discussed.

Case studies were used to illustrate how coastal communities and socio-economic indicators can be linked to marine ecosystems and socio-ecological models. The importance of assessing the performance of indicators, their precision, and statistical power was also discussed.

The final lectures outlined the use of economic and social indicators for policy and decision-making, and, in particular, fisheries management. Participants discussed the advantages of knowing how to communicate the salient information the indicators provide to a range of different audiences - thereby bridging the gap between research and information that is practical and useful for management.

Table 2. Examples of simple, complex, and even more complex indicators used to summarize complex and often disparate datasets and present information in a simple and clear way. Compiled by Alida Bundy.

Simple indicators ● Biomass of functional groups e.g. piscivores, omnivores, zoopiscivores, benthivores, detritivores ● Sea surface temperature, pCO_2, salinity, nitrate ● Number of fishery jobs, average wage, average price of fish
Complex indicators ● Stoichiometric ratios e.g. Redfield ratio (C:N:P = 106:16:1) ● Large Fish Indicator, Large Species Indicator ● Proportion of predatory fish in the community ● Pelagic : demersal ratio ● Landed value/GDP ● Average fisheries wage/average national wage
Even more complex indicators ● Shannon Index of diversity ● Pielou's species evenness ● 4D EEI ● Slope of the biomass spectrum ● Ocean Health Index

3.6 The practical sessions and group projects

Each afternoon there were “hands on” practical sessions were participants were able to use techniques and methods that had been covered in the lectures, to analyse a data set comprising a socio-ecological system. All lecturers were available to assist and advise when required. Once again, the benefits of limiting the number of participants to a maximum of 60 participants, were apparent. Lecturers had sufficient time to adequately explain or assist the participants, either with individual queries, or if a group was having difficulties or needed clarification.

There were also groups projects, that entailed using real-world data to undertake a socio-ecological analysis and report on the state of the system and the management trade offs (see Appendix VIA for the guide notes for the group projects). Participants were pre-assigned to groups, to ensure gender balance, geographic and skill set diversity (see Appendix V1B). Some groups opted to use the personal datasets of a group-member. In these instances, the first step was to explain the data and provide information about where it was collected, timeframe, etc. in which it was collected, to the rest of the group. Because the task was to perform a socio-ecological analysis, some datasets required data-augmentation. If the dataset had only bio-physical data, the group needed to find social or economic data from the internet to support it. If time series data for pelagic fish catches in a particular area was available, the group had to find relevant social and economic data to undertake the socio-ecological analysis. A list of useful websites to source data was provided (see Appendix VII).

In general, the groups worked well together, with everyone doing different tasks in order to complete the project on time. However, when a group member's data was used, rather than the data provided by the organisers, there tended to be "leadership issues" as the data owner inevitably ended up taking a leadership role in the group

The week ended with groups presenting their results to a panel of "managers", who provided feedback on the way they had tackled the project, their results and also the way they presented these and any management recommendations. Everyone found it to be an excellent learning experience, not only in terms of working together in a very diverse (multi-cultural and multi-disciplinary) group, but also getting feedback from managers and other decision- and policy-makers. They found this to be extremely valuable, in terms of their analytical methods, as well as their communication skills and techniques.

3.7 Poster presentations

All participants were asked to bring a paper showcasing their research, which they presented during an evening poster session on the first evening (see Appendix IV for the abstracts). Although one or two people suggested that it should be held later in the week (mostly to allow them to overcome jetlag), the organizers thought that it was a very successful activity that generated a great deal of interest, interactions and discussion, and proved to be a good "ice-breaker" enabling the participants and lecturers to get to know each other early on.

The job of evaluating and providing written feedback about each poster was no small feat! However, the positive feedback and constructive criticism was found to be extremely useful and this is something that IMBER will definitely continue at future summer schools.

4.0 Conclusions

To contribute to building the capacity of the IMBER and international marine science community, that works on global change issues at the interface of human and marine systems.

The IMBER ClimEco4 summer school brought together process and observation scientists, modellers from both the natural and social sciences, and others with an interest in using empirical data such as indicators of climate change, climate impacts and marine ecosystem services, and their links to socio-economic indicators, and policy information related to climate-ecosystem interactions.

Through this learning experience, and through the increased networking and collaborations that the summer school facilitated, this will contribute to the community of inter-disciplinary marine researchers who work at the interface of natural and human systems. This is a developing community, and the IMBER summer school's focus on human-natural science interactions provided training that is not available (or is very limited) in traditional academic curricula.

To make more new researchers aware of, and provide them with the techniques and methods to address and evaluate climate change impacts on marine ecosystems, and how to transform data into usable products, tools or advice.

The topic (using indicators to assess marine socio-ecological systems) was considered to be essential and timely, and very necessary to equip researchers with an awareness of, and with the tools to address and evaluate climate change impacts on marine ecosystems and the consequences for their management. Participants were introduced to a range of indices that can be used for evaluating the ecological (e.g. biodiversity, production) and socio-economic (e.g. management and societal benefit) aspects of marine ecosystems. They were also presented ways in which these indices are constructed (particularly useful for process/observation scientists), used (by both natural and social science modellers), and combined to inform policy and decision-making. Information on climate change, databases (how and where to acquire large data sets and how to manage them), data analysis methods for indicators (statistical methods), using indicators with models (ecosystem, socio-economic models), and criteria and use of indicators for informing marine management and policy was also provided. "Hands-on" practical sessions gave participants the opportunity to "try out" databases (their own, or provided examples), indicators, and models to apply some of the concepts covered in the lectures. In the group projects, they experienced selecting and developing indicators, how to evaluate trade-offs in developing these. On the final day, they presented an analysis of their application and use for the ecosystem, that required newly learned skills for communicating with a variety of audiences.

To contribute to the improvement of information and knowledge transfer in global change research to more effectively manage the impacts and consequences to human and marine systems.

The summer school helped bridge the gap between research and management and policy, to ensure that marine systems research is incorporated into governance processes. In addition to learning about climate change pressures on marine systems, and how to analyse and model these complex systems using indicators, Dr. Keith Sainsbury, a communications specialist presented ways to improve communication to an array of different audiences. Dr. Sainsbury is very well-positioned to speak on this as he has worked "on both sides" – he is a marine science researcher, and subsequently worked in both private and government institutions involved in marine fisheries management.

The summer school exposed the participants to working in multicultural and multidisciplinary environment. It provided the opportunity for participants to learn from international and multidisciplinary researchers in a small, participation-based setting. The summer school sessions also produced many useful discussions concerning how to best for natural scientists to connect and collaborate with social scientists and policy-makers, to develop science-based policy options. The

group projects were specifically designed to ensure that participants worked in a multicultural, multidisciplinary situation. Participants were assigned to groups comprising people from different countries and where possible, different scientific disciplines.

By all accounts, ClimEco4 was a great success, and participants came away equipped with the knowledge of how to source, analyze, and transform data into usable products, tools, or advice. In addition to the training, and perhaps even more beneficial, were the opportunities the course offered for networking and interacting with both established researchers and with their peers from a variety of different scientific disciplines. Linkages like these are essential for fostering interdisciplinary and collaborative science in the future.

5.0 Future Directions

IMBER summer schools are held every second year and plans are already underway for ClimEco5. Noting that participants from South America are often excluded for the summer schools due to high travel costs, ClimEco5 will be held in Natal, Brazil in August 2016, in the hope of enabling local participants to attend. Deliberations have already started about the potential theme. It has been suggested that a topic that addresses data and monitoring, modelling through to management recommendations, and ways to communicate, focusing on case studies, would be appropriate.

As evidenced by the evaluations of previous summer school participants, they are important capacity building activities for IMBER. Students and early-career researchers appreciate learning about techniques and methods used in IMBER's cutting-edge research. They particularly benefit from the practical sessions, where they are able to test and understand the ideas put forward in the lectures, with experts on-hand to assist when needed. This format will definitely be incorporated into future IMBER summer schools.

IMBER continues to foster research at the interface of social and natural systems and this will continue in all upcoming IMBER activities. In October 2015, IMBER will convene IMBIZO IV (IMBIZO is the Zulu word for a gathering) that will bring together researchers and students from an array of disciplines concerned with marine research to discuss Marine and Human Systems: Addressing Multiple Scales and Multiple Stressors. At this meeting, there will also be several workshops aimed at students and early-career researchers to help them navigate the marine science environment more smoothly. This includes a workshop on scientific writing and publishing and another on how to write a good (and hopefully successful!) funding proposal. By building the capacity of young researchers and training them to work in multidisciplinary groups to be able to address issues relating to the marine environment and the humans that depend on the goods and services that it offers, IMBER is contributing to building the emerging community who work at the interface of marine and human systems.

IMBER will also continue the APN's goal of helping participants from less developed countries attend IMBER events and activities. By seeking funding such as that generously provided by the APN for the IMBER ClimEco4 summer school, we hope to enable more participants from these regions to benefit from the expert training, advice and collaboration these events can offer.

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The Ocean Data Interoperability Platform (ODIP; http://www.odip.org/) project aims to establish a coordination platform (EU/USA/Australia/IOC-IODE) to achieve interoperability of ocean and marine data infrastructures.

The COOPEUS (http://www.coopeus.eu/) project aims for global integration of existing data infrastructures by bringing together scientists and users from EU and US environmental research infrastructure projects.

The European Marine Observation and Data Network (EMODnet; http://www.emodnet.eu/) is a consortium of organisations within Europe that assembles marine data, data products and metadata from diverse sources in a uniform way.

Australia's Integrated Marine Observing System (IMOS; http://www.imos.org.au/) is designed to be a fully-integrated, national system, observing at ocean-basin and regional scales, and covering physical, chemical and biological variables.

The U.S. Integrated Ocean Observing System (U.S. IOOS; http://www.ioos.noaa.gov/) is a vital tool for tracking, predicting, managing, and adapting to changes in our ocean, coastal and Great Lakes environment. U.S. IOOS delivers the data and information needed, so that decision-makers can take action to improve safety, enhance the economy, and protect the environment.

MyOcean (http://www.myocean.eu/) is a European marine core service. Its objective is to provide users with the best generic information available on the state of the ocean. MyOcean is committed to develop and run a European service based on a worldwide capacity for ocean monitoring and forecasting, using observations data, modelling and assimilation systems.

Eurostat is (http://epp.eurostat.ec.europa.eu/) the statistical office of the European Union situated in Luxembourg. Its task is to provide the European Union with statistics at European level that enable comparisons between countries and regions.

The IndiSeas project (http://www.indiseas.org/) is a multi-institutes collaborative effort. One or two scientific experts from each ecosystem represented have calculated the necessary indicators and provided background information and overview of the status of their ecosystem. Indicator series currently extend to 2010, but the database will be updated on a regular basis

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Appendices

Appendix I: ClimEco4 Organising Committee

Name	Affiliation	E-mail
Stéphane Pesant ClimEco4 Convener	University of Bremen Bremen, Germany	spesant@marum.de
Ingrid van Putten ClimEco4 Convener	CSIRO Marine and Atmospheric Research Hobart, Tasmania, Australia	ingrid.vanputten@csiro.au
Eileen Hofmann Chair: IMBER Scientific Steering Committee	Old Dominion University Norfolk, USA	hofmann@ccpo.odu.edu
Lisa Maddison	IMBER International Project Office, Institute of Marine Research Bergen, Norway	lisa.maddison@imr.no
Fang Zuo	IMBER Regional Project Office East China Normal University Shanghai, China	zuo.fang.ecnu@gmail.com

Appendix II: ClimEco4 Participants

A: Lecturers

Name	Affiliation	E-mail
Alida Bundy	Bedford Institute of Oceanography, Dartmouth, Canada	alida.bundy@dfo-mpo.gc.ca
Jiahua Cheng	East China Sea Fisheries Research Institute Shanghai, China	ziyuan@sh163.net
Elizabeth (Beth) Fulton	CSIRO Marine and Atmospheric Research Hobart, Tasmania, Australia	beth.fulton@csiro.au
Eric Galbraith	McGill University Montreal, Canada	eric.galbraith@mcgill.ca
Scott Large	NOAA-Fisheries Woods Hole, MA, USA	scott.large@noaa.gov
Stéphane Pesant	PANGEA, University of Bremen, Bremen, Germany	spesant@marum.de
Yongsong Qiu	South China Sea Fisheries Research Institute Guangzhou, China	qys@scsfri.ac.cn
Keith Sainsbury	CSIRO & University of Tasmania Hobart, Tasmania, Australia	ksainsbury@netspace.net.au
Rashid Sumaila	Fisheries Economics Research Unit, University of British Columbia Vancouver, Canada	r.sumaila@fisheries.ubc.ca
Ingrid van Putten	CSIRO Marine and Atmospheric Research, Hobart, Tasmania, Australia	ingrid.vanputten@csiro.au

B: Students and Early-career Scientists

Name	Affiliation	E-mail
Lubna Alam	Institute for Environment and Development (LESTARI) Selangor, Malaysia	lubna_762120@yahoo.com
Ricardo Arruda Monteiro da Silva	Universidade Federal do Rio Grande (FURG) Rio Grande, Brazil	cadoarruda@gmail.com
Ana Azevedo	University of Aveiro, Aveiro, Portugal	de.azevedo@ua.pt
Andrii Bagaiev	National Academy of Sciences of Ukraine Sevastopol, Ukraine	bagaiev.andrii@gmail.com
Pamela Barret	University of Washington Seattle, USA	barrettp@uw.edu
Hadar Berman	The Hebrew University of Jerusalem Jerusalem, Israel	hadarberman@gmail.com
Bayosa Aya Cariño	University of the Philippines Diliman, Philippines	aya.carino@gmail.com
Yan Chang	East China Normal University Shanghai, China	cyyc2010@126.com
Xujing Davis	Woods Hole Oceanographic Institution Woods Hole, USA	xdavis@whoi.edu
Massimo Di Stefano	Rensselaer Polytechnic Institute, Troy, USA And Woods Hole Oceanographic Institute, Woods Hole, USA	distem@rpi.edu
Yongliang Duan	First Institute of Oceanography Qingdao, China	ylduan@fio.org.cn
Sanna Durgappa	Indian Institute of Science (IISc) Bangalore, India	durgappa@astra.iisc.ernet.in
Pierre Failler	CEMARE, University of Portsmouth, Portsmouth, United Kingdom	pierre.failler@port.ac.uk

Name	Affiliation	E-mail
Yang Feng	Virginia Institute of Marine Sciences, Gloucester Point, USA	cyfeng@vims.edu
Maria Fossheim	Institute of Marine Research Tromsø, Norway	maria.fossheim@imr.no
Giovanni Galli	National Institute of Oceanography and Experimental Geophysics (OGS) Borgo Grotta Gigante, Italy And University of Trieste, Trieste, Italy	ggalli@ogs.trieste.it
Grinson George	Central Marine Fisheries Research Institute Kochi, India	grinsongeorge@gmail.com
Eva Giacomello	Centre of IMAR University of the Azores Horta, Portugal	evagiacomello@uac.pt
Dukki Han	Gwangju Institute of Science and Technology Gwangju, South Korea	dukkihan@gist.ac.kr
Carie Hoover	Fisheries and Oceans Canada Winnipeg, Canada	Carie.Hoover@dfo-mpo.gc.ca carie@cariehoover.com
Mahmudul Islam	Sylhet Agricultural University Sylhet, Bangladesh	mahmud2512@googlemail.com
Tianyu Jiang	Oak Ridge National Laboratory Oak Ridge, USA	jiangt@ornl.gov
Rekha J. Nair	Central Marine Fisheries Research Institute Kerala, India	rekhacmfri@gmail.com
Maria-José Juan-Jordá	AZTI Tecnalia, San Sebastian, Spain and Simon Fraser University, Vancouver, Canada	mjuan@azti.es
Lucas Kavanagh	McGill University Montreal, Canada	lucas.kavanagh@mail.mcgill.ca

Name	Affiliation	E-mail
Shubham Krishna	GEOMAR - Helmholtz Centre for Ocean Research Kiel, Germany	skrishna@geomar.de
Somy Kuriakose	Central Marine Fisheries Research Institute Kerala, India	somycmfri@gmail.com
Kuo-Wei Lan	National Taiwan Ocean University Keelung, Taiwan R.O.C.	kwlan422@gmail.com
Vasiliki Lianou	National & Kapodistrian University of Athens Athens, Greece	vlianou@geol.uoa.gr
Jesse Lopez	(CMOP) Oregon Health & Science University Portland, OR, USA	lopezjes@ohsu.edu
Toni Mizerek	Macquarie University Sydney, Australia	Toni.mizerek@mq.edu.au
Yuri Oh	Korea Institute of Ocean Science & Technology Ansan, South Korea	ourmail@kiost.ac
Natalia Ospina-Alvarez	University of Warsaw Warsaw, Poland	nospina.alvarez@me.com; nospina@chem.uw.edu.pl
Rajani Panchang	Agharkar Research Institute (MACS-ARI) Pune, India	rajanipanchang@gmail.com
Ravindra Rattan	The University of the South Pacific Suva, Fiji	ziad.rattan@gmail.com
Tyler Rohr	MIT/WHOI Joint Program in Oceanography Woodshole, USA	trohr@mit.edu
Ginevra Rosati	National Institute of Oceanography and Experimental Geophysics (OGS) and University of Trieste, Italy Trieste, Italy	grosati@ogs.trieste.it

Name	Affiliation	E-mail
Petra Schoon	Lund University Lund, Sweden	petra.schoon@geol.lu.se
Xiujuan Shan	Yellow Sea Fisheries Research Institute Qingdao, China	shanxj@ysfri.ac.cn
SM Sharifuzzaman	University of Chittagong Chittagong, Bangladesh	sharifuzzaman@cu.ac.bd
Zhonghua Shen	University of Tokyo Tokyo, Japan	0233655726@mail.ecc.u-tokyo.ac.jp
Feng Shi	Chinese Academy of Sciences Beijing, China	shifeng@lasg.iap.ac.cn
Paul Suprenand	University of Florida	psuprena@ufl.edu
Katrin Tirok	University of KwaZulu-Natal, Durban, South Africa	katrintirok@gmail.com
Nandipha Mhlongo	Department of Agriculture, Forestry, and Fisheries and University Cape Town, Cape Town, South Africa	NandiphaM@nda.agric.za
Xiaona Wang	East China Normal University Shanghai, China	wangxiaonaxmu@163.com
Ashvin Wickramasooriya	University of Peradeniya Peradeniya, Sri Lanka	awickramasooriya@gmail.com
Joo-Eun Yoon	Korea Institute of Ocean Science & Technology Ansan, South Korea	eliteremje@gmail.com
Chengyi Yuan	Tianjin University of Science and Technology Tianjin, China	chengyiyuan9@gmail.com
Xunchi Zhu	East China Normal University Shanghai, China	zhuxch2008@163.com

Appendix III: Programme for ClimEco4 Summer School – Delineating the Issues of Climate Change and Impacts to Marine Ecosystems: Bridging the Gap between Research, Assessment, Policy and Management - (4-9 August 2014, East China Normal University, Shanghai, China)

DAY 1 – MONDAY 4 AUGUST 2014	
General introduction to marine climate change and indicators	
09:00-09:45	Welcome address and overview of the course **Prof. Yunxuan Zhou (SKLEC),** **Lisa Maddison, Ingrid van Putten, Stéphane Pesant**
09:45-10:30	Delineating the issues of climate change and impacts to marine ecosystems **Beth Fulton**
10:30-11:00	*Break*
11:00-11:45	Indicator basics – What they are, why we use them and what they can be used for **Alida Bundy**
11:45-12:30	Indicators of climate change and climate impact on marine ecological systems (biophysical perspective) **Scott Large**
12:30-13:30	*Lunch*
State and pressure indicators and modelling basics	
13:30-14:15	Climate change and marine biogeochemistry at different time scales **Eric Galbraith**
14:15-15:15	Socio-economic and governance indicators and climate impact (including ecosystem services approach) **Ingrid van Putten, Rashid Sumaila**
15:15-15:45	*Break*
Working group projects	
15:45-17:00	Introduction to group work, divide into groups **Ingrid van Putten, Beth Fulton (and all other lecturers)**
17:00-19:00	Poster session – Participants present a poster relating to their research (Drinks and snacks will be served) **All lecturers**

DAY 2 – Tuesday 5 AUGUST 2014	
Data and databases	
09:00-10:00	Modelling basics and modelling in the context of indicators **Beth Fulton**
10:00-10:45	General circulation models **Eric Galbraith**
10:45-11:15	*Break*
11:15-12:00	Selecting indicators **Alida Bundy**
12:00-13:00	Access to observational data and indicators **Stéphane Pesant**
13:00-14:00	*Lunch*
Working group projects	
14:00-15:30	Commencement of group work **All lecturers will be present to help with ideas and approaches**
15:30-16:00	*Break*
16:00-17:00	Group work continued **All lecturers**

DAY 3 – Wednesday 6 AUGUST 2014	
Analyses refresher and statistics primer – how to analyse data	
09:00-09:45	Data analysis methods (including methods for data quality control) **Scott Large**

09:45-10:30	Methods for nonlinearity exploration in data: Detecting 'tipping points', developing decision criteria empirically and analytically. **Scott Large**
10:30-11:00	*Break*
11:00-11:45	Applied statistical techniques (PCA and Cluster analysis) **Scott Large, Beth Fulton**
11:45-12:30	Applied statistical techniques (analysis of networks) **Scott Large, Ingrid van Putten**
12:30-13:30	*Lunch*
13:30-15:00	Interactive assessment and discussion of three scientific papers (Fulton et al 2010, Mora et al 2009, Halpern et al 2012) **Rashid Sumaila, Beth Fulton and others**
15:00-15:30	*Break*
Working group projects	
15:00-17:00	Group work continued **All lecturers**

DAY 4 – Thursday 7 AUGUST 2014	
How to use indicators in ecological and socio-economic models	
09:00-10:00	Publishing, discovering and re-using scientific data **Stéphane Pesant**
10:00-11:00	Linking coastal communities and socio-economic indicators to marine ecosystems **Ingrid van Putten**
11:00-11:30	*Break*
11:30-12:30	Using indicators with ecological and socio-economic models **Rashid Sumaila**

12:30-13:30	*Lunch*
13:30-14:30	Performance of indicators **Alida Bundy**
14:30-15:00	*Break*
Working group projects	
15:00-17:00	Group work continued **All lecturers**

DAY 5 – Friday 8 AUGUST 2014	
Using indicators for policy, decision-making and management	
09:00-09:30	Impacts of climate change and fishing on fisheries **Yongsong Qiu**
09:30-10:00	Use of indicators in fisheries management **Jiahua Cheng**
10:00-11:00	Use of indicators in policy and management **Keith Sainsbury**
11:00-11:30	*Break*
11:30-12:30	Use of economic and social indicators in fisheries management and policy **Rashid Sumaila**
12:30-13:30	*Lunch*
13:30-14:30	Communicating indicators to a range of audiences **Keith Sainsbury**
14:30-15:00	*Break*
Working group projects	

15:00-17:00	Preparation for group presentations **All lecturers**
19:30	Summer school dinner at the Shanghai Min Restaurant

DAY 6 – Saturday 9 AUGUST 2014	
Participant presentations	
09:00-11:00	Group presentations of their ecosystem assessment **All lecturers**
11:00-11:30	*Break*
11:30-12:30	Group presentations of their ecosystem assessment **All lecturers**
12:30-13:30	Closing discussion **All lecturers**

Appendix IV Poster Presentation Abstracts

Study of potential impacts of climate change on fisheries sector and adaptation options in Malaysia

Lubna Alam[1], Mazlin Mokhtar, Goh Ta and Lee Ern

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

Abstract

Climate change has attracted much scientific and public attention over the last few years and is expected to influence marine ecosystems throughout the world influencing fish, fisheries, and aquaculture programmes. The ecosystem productivity, fish vital rates (growth, recruitment, and mortality), fish distribution and migration patterns, species composition, biodiversity, phenology, and input costs are the sector predicted to be influenced by climate change. Thus, climate change poses new challenges to the sustainability of fisheries and aquaculture systems, with serious implications for the 520 million people who depend on them for their livelihoods, and the nearly 3 billion people for whom fish is an important source of animal protein. However, in case of Malaysia, the fisheries sector is considered as an important sub-sector in playing significant role in the national economy. Apart from contributing to the national Gross Domestic Product (GDP), it is also a source of employment, foreign exchange and a source of protein supply for the population in the country. The fisheries sector of Malaysia is not free from the threat of climate change as this country is considered as one of the highly vulnerable countries due to climatic changes. But unfortunately, research on this promising issue is still lacking in Malaysia. Therefore our future plan is to assess the vulnerability of fisheries sector due to changing climate and to propose possible adaptation options for Malaysian fisheries. This empirical study will use both primary and secondary data. Primary data will be collected through structured questionnaire interviews, interviews with community leaders and field observations at the fisherman community. Subjects of focus for the questions will be included: (i) the fisher's experiences of fishing; (ii) the fisher's perception on management regimes; (iii) the fisher's perception of climate change and its impact on the fisheries; and (iv) the fisher's perception of and ideas for adaptation. The integrated fisheries risk analysis method for ecosystems model (IFRAME) will be utilized to form an ecosystem approach to assess the impact of climate change on fisheries. The adaptation strategies will be investigated based on the assessed impact of climate change on fisheries and the focused sectors will be: adaptation to impacts of climate change on fishery habitat, adaptation to direct impacts of climate change on fishery stocks, adaptation to impacts on the harvesting sector and adaptation to impacts on fishing communities. The decision tools like benefit-cost analysis, cost effectiveness analysis and multi-criteria analysis will be utilized to assist decision-makers in choosing between, or prioritizing, alternative adaptation measures.

Surface ocean pCO_2 variability and sensitivity in the southwestern Atlantic Ocean

Ricardo Arruda[1] and Paulo Calil

[1] Universidade Federal do Rio Grande, FURG, Rio Grande, Brazil

Abstract

Surface Ocean pCO_2 is the parameter that ultimately controls the ocean-atmosphere flux of CO_2. pCO_2 variability is driven by temperature (T), salinity (S), inorganic dissolved carbon (DIC) and alkalinity (ALK). Ocean pCO_2 in the Southwestern Atlantic Ocean was assessed through climatological runs of a coupled physical-biogeochemical model, with the hydrodynamical model ROMS and a NPZD-Carbon model. Results were compared to available observations from SOCAT. The pCO_2 sensitivity to each of its main drivers (T, S, DIC, ALK) was estimated through anomalies and applying small perturbations to the pCO_2 equation. A spatial analysis was made throughout the continental shelf (15° S to 55°S), and a temporal analysis was made dividing the shelf into three areas, the South Brazilian, the Southeast Brazilian and the Patagonian continental shelf. The modeled pCO_2 ranged between 200 and 500 µatm, with the highest pCO_2 in the inner continental shelves and in the low latitudes. Spatial analysis of sensitivity showed that DIC and temperature are the main drivers of pCO_2 variability. With temperature representing the most important driver in the Southernmost and Northernmost regions, being responsible for changes up to 100 µatm in pCO_2. DIC contributes to a cross shelf gradient of pCO_2, from the continental shelf break to a nearshore maxima. Salinity and alkalinity play less important roles in regulating pCO_2 in this region. The temporal analysis of the sensitivity showed that the most expressive anomalies of pCO_2 occur in the South Brazilian and in the Patagonian shelves. In the South Brazilian continental shelf the anomalies are mainly driven by changes in temperature, whilst in the Patagonian shelf both temperature and DIC are important drivers to these anomalies. The Southeast Brazilian continental shelf is less variable, with DIC, ALK and temperature affecting the pCO_2 with the same magnitude. Overall, when comparing with the few SOCAT data available for this area, the modeled pCO_2 represents the seasonal pattern, although in some months the model underestimates pCO_2 by 20 µatm to 40 µatm. As this area of the Atlantic Ocean has few observations available, numerical modeling becomes an important tool for the investigation of pCO_2 dynamics and variability. Our results could be used as baseline for planning future studies about climate change and processes affecting surface ocean pCO_2. Overall, the variability of biogeochemical variables is represented by the model. Temperature and DIC are the main drivers of pCO_2 variability, but their importance varies in different regions and in different seasons.

Modelling the Processes of Intertidal Seagrass in Ria de Aveiro (Portugal)

Ana Azevedo[1], Ana Isabel Lillebø, João Lencart e Silva and João Miguel Dias

[1] University of Aveiro, Aveiro, Portugal

Abstract

Seagrasses are rooted flowering plants, growing in marine and estuarine environments. They may form extensive and productive meadows that provide several goods and services to coastal populations. Nevertheless, these habitats are declining at a worldwide scale, as a result of human

driving forces such as the coastal development and climate change, with additional impact effects for the species depending on them.

Since they are important ecological quality indicators of the coastal zone, increasing the knowledge of these systems is essential for management strategies to preserve and improve the health and environmental quality. To achieve that, modelling approaches arise as useful supportive tools that will be adopted, together with the construction and evaluation of multiple stressor scenarios (e.g. storm surges, heat waves). This way, and considering the context of global climate change, the resilience of the system to multiple stressors could be assessed. Attending the Summer School ClimECO4, it is expected to learn more about the linking between scientific knowledge and management or policy, as well as understand how climate change impacts and the potential alterations on the providing services and ecological functions could be linked to indices for socio-economic and policy information in relation to climate-ecosystem interactions. Finally, it is expectable to learn best-practices on providing useful and understandable information to coastal managers, for a better comprehension and using planning of coastal areas, particularly those in the vicinity of very dynamic and sensitive habitats such as seagrass meadows.

3D Multidisciplinary numerical model of polychlorinated biphenyl dynamics on the Black Sea north-western shelf

Andrii Bagaiev

Marine Hydrophysical Institute of National Academy of Sciences of Ukraine

An original 3D model of PolyChlorinated Biphenyls (PCB) dynamics in the Black Sea has been developed to provide a robust predictive tool in case of accidental spill at sea. PCBs are eco-toxicants, highly resistant to degradation, hence are capable of long-range transport, bioaccumulation in human and animal tissue. Being lipophilic, PCBs demonstrate the distinguishing sorption/desorption activity on the organic matter particles and in sediment. The model consists of one-way coupled sub-systems as follows: an operational ocean circulation model, a module of transport and transformation of suspended particulate matter, and a PCB dynamics module. Production of suspended particulate matter and gravitational settling, first-order decomposition rate and the water-sediment exchange are taken into account. PCB module includes its concentration in solution, concentration on suspended particulate matter and concentration in the upper layer of sediment. Adsorption and desorption as well as the reversible PCB fluxes at the bottom are parameterized explicitly while PCB cross-boundary fluxes are taken into account implicitly in the generalized form. The model is validated on the historical interdisciplinary data sets by means of over 200 spin-ups. The model is upgraded to evaluate efficiency of deployment of the artificial active sorbent as a countermeasure in PCB spill response. The approach developed is promising with respect to risk assessment problem and development of decision support system. The model allows generalization to any of the environmental pollutants and Hazardous and Noxious Substances (HNS).

Using high-resolution sampling along CLIVAR transects to investigate ocean changing biogeochemical cycling of trace elements

Pamela Barrett[1], Joseph Resing, Nathan Buck, William Landing, Rachel Shelley and Peter Morton

[1] University of Washington, Seattle, USA

Abstract

Trace elements in the ocean can function as essential micronutrients that modulate primary productivity and ocean CO_2 uptake (e.g., Fe, Zn) or as potential toxins (e.g., Cu, As). Incorporation of trace element cycling into global ocean biogeochemical models will be important to understand the state of future ocean carbon cycling, ecosystem health, and global climate feedbacks. A dedicated trace-element sampling program has been carried out on 11 U.S. CLIVAR-CO_2 Repeat Hydrography cruises since 2003, transecting the major ocean basins. This work has produced high-resolution sections of the distribution of selected trace elements in the upper 1000 m of the global ocean which have been used to identify and characterize sources, sinks, and processes that control the internal cycling of trace elements in the upper ocean. Repeat observations of trace element distributions in the North Atlantic have been made along CLIVAR section A16N, occupied in 2003 and 2013. Tracers for aerosol dust deposition on the surface ocean (Al, Ti), a major pathway for delivery of Fe to the ocean, were found at higher concentrations in the upper ocean in 2013, indicating increased aerosol dust Fe delivery to the North Atlantic over the last decade. In contrast, ocean inventories of trace metal species originating primarily from anthropogenic aerosol sources (e.g., Cu, Ni) declined in 2013. Repeat observations of trace element distributions will better constrain oceanic budgets, improve model parameterizations, and allow predictions about the impact of changing trace element distributions due to natural and anthropogenic forcing on future climate.

The effect of Milankovich cycles on the emergent of a marine ecosystem

Hadar Berman

The Hebrew University of Jerusalem

Abstract

We study the effect of changes in photosynthetically active radiation (PAR) due to Milankovich cycles on the marine ecological system. This is done using MITgcm Darwin 1D model. We conduct a series of experiments to test the sensitivity of the ecosystem structure to long term variations in solar insolation.

Early warning system for monitoring harmful algal blooms in the Sorsogon-Maqueda-Sapian Triangle (SMS-Tri) using satellite ocean color imagery

Bayosa Aya B. Cariño[1], Aldwin Almo and Laura David

[1] Marine Science Institute, University of the Philippines Diliman, Philippines

Abstract

Remotely-sensed, satellite ocean color images from 2002-2012 were analyzed to device an early warning system for monitoring harmful algal blooms (HABs) in the Sorsogon-Maqueda-Sapian Triangle (SMS-Tri). The MODIS Aqua dataset for chlorophyll a concentration (4 km resolution) was compared against local declarations of shellfish bans which, in this study, is used as a proxy for blooms of PSP toxin producing dinoflagellates. The data used for the analysis is from July 4, 2002 to Jan 9, 2012 for a total of 439 weekly composites which were analyzed and compared to the local shellfish ban declarations from 2002 to 2010. When the chla anomaly (difference between that week's chla concentration and the average concentration) goes beyond a certain threshold, this indicates a potential harmful algal bloom (HAB). Average concentration was calculated in 2 ways - seasonal concentration (monthly average over data for all the years) or running average (average value for two months prior to the week being analyzed). The threshold MODIS chla concentration was found to be 0.01 mg/m^3 chla, above which monitoring is recommended to verify the presence of a HAB in that locality. Using this threshold, it was found that the 4 km resolution of MODIS can show potential blooms at the bay level.

As an early warning for HABs, this tool is useful in aiding shellfish management and public health in responding to rapidly developing HABs in a timely, efficient manner. There is still a chance that this tool might not be able to detect a bloom if its signal is not detected by the satellite – a subsurface bloom, a bloom that is too small, or simply due to the presence of clouds. There is also a chance that a potential bloom that this tool will detect is not harmful if the high concentration of chla is due to non-harmful algae. The actual threshold limits should also be calibrated if applied to localities beyond the SMS-Tri or for other species of blooms.

The behavior of dissolved inorganic selenium in the Changjiang Estuary

Yan Chang[1,2], Jing Zhang[2], Jianguo Qu[2], Guosen Zhang[2], Anyu Zhang[1] and Ruifeng Zhang[2]

[1] School of Ecological and Environmental Sciences, East China Normal University, Shanghai 200062, PR China

[2] State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, PR China

Abstract

To thoroughly investigate the behaviors of inorganic selenium species in Changjiang Estuary, samples were taken in summer (July 2011) and winter (March 2012). The dissolved inorganic selenium (DISe) averaged 1.79 nmol/L in summer and 1.24 nmol/L in winter, the selenite to selenate ratio (Se(IV)/Se(VI)) was 0.42 in summer and 0.61 in winter. The data showed Se(IV) and Se(VI) behave strictly conservatively in winter while non-conservatively in summer in the estuary due to the adsorption by suspended particulate matter and the assimilation by the phytoplankton. The distribution of selenium in Changjiang Estuary was controlled by Changjiang riverine input, Taiwan Warm Current and Yellow Sea Coastal Current with specific Se(IV)/Se(VI) ratio 'signature' which could remain in winter while be altered in summer. The Se(IV) concentration was related to the

nitrate, silicate and phosphate concentration in the estuary. The DISe and Se(IV) concentration was comparable with other coastal regions and estuaries which was in the natural levels.

Prediction of silver hake distribution on the Northeast U.S. shelf based on Gulf Stream path index and autoregressive models

Xujing Jia Davis, Terrence M. Joyce and Young-Oh Kwon

Abstract

Over the past ~40 years, the distribution of silver hake (SH) on the Northeast U.S. shelf is found to be closely related to changes in the latitude of the Gulf Stream (GS) path. The correlation coefficient between the fall GS position and the center of biomass (COB) of spring SH reaches 0.75 when the GS leads the SH for 0.5 year. Based on this lead-lag relationship and low-frequency variability of GS position with a dominant period of ~9-10 years, the GS path index is used as a predictor for the COB of SH in linear autoregressive (AR) models. The goal of this study is then to optimize the AR model for the prediction of SH based on the observed changes in GS position. Fall GS position is first predicted out to 5 years using a 5^{th} order AR model and the observed GS position in preceding years. We propose an optimization process to choose best AR coefficients based on a new combined skill parameter. We then use this predicted GS position to further predict the COB of SH in subsequent spring. Three different AR models are compared for the SH prediction. The predicted SH time series can explain as much as 69% of the variance of the observation for the 1^{st} year prediction and 41 % for the 5^{th} year prediction. Our results indicate that including GS as a predictor produces better prediction skills of SH COB than the AR model prediction solely based on the observed SH time series

Development of cyberinfrastructure to facilitate collaboration and knowledge sharing for marine Integrated Ecosystem Assessments

Massimo Di Stefano, Linyun Fu, Patrick West, Xiaogang Ma, Stace Beaulieu and

Peter A. Fox

Abstract

Here we present an approach to help scientists collaborate in multi-disciplinary research, providing a wide spectrum of software tools for data science and enabling the reproducibility of their research outputs. The main tool is based on the extensive use of a web application, the IPython Notebook, that gives the scientists the ability to work on very diverse and heterogeneous data and information sources, providing an effective way to share the source code used to generate data products and associated metadata as well as save and track the workflow provenance. A key feature in IPython (Interactive Python) is that metadata, embedded in the Notebook, can be generated during the access and processing of data. We are presently developing functionalities to collect the provenance generated at each run of the workflow and store this metadata in the JSON-LD (JSON for Linking Data) standard format. In this way it is possible to record the provenance for derived data products, to trace back to their original sources and the processing conducted to generate them.

Seasonal variations of the Java Upwelling System and its biogeochemical responses in the southeastern Indian Ocean

Yongliang Duan, Weidong Yu, Lin Liu, and Huiwu Wang

Abstract

In the monsoonal Indian Ocean, Eastern Indian Ocean Upwelling (EIOU), driven by the southeastern monsoon, exhibits more profound impacts at regional and global climate through its intensive interaction with the atmosphere, i.e., the Indian Ocean Dipole (IOD). EIOU is very unique not only because it is driven by boreal summer monsoon wind but also it has the porous eastern boundary with several straits to pass the information from Pacific Ocean. The seasonal monsoon-driven Java Upwelling System, together with the circulation convergence and water mass mixing by Indonesian Throughflow (ITF), South Java Current, South Equatorial Counter Current, makes the region between south Indonesia and northwest Australia one unique area of high importance for the fishery. However, the ecosystem response to upwelling is poorly sampled and multidiscipline research is highly desired. Here we use the high-revolution satellite remote data and advanced cruising data to illustrate the seasonal variations of the Java Upwelling System and its detail biogeochemical responses in the southeastern Indian Ocean. The results show that the Java Upwelling System, driven dominantly by the southeastern monsoon, occurs in Jun.-Oct. And it favors the high sea surface chlorophyll-a concentration and supplies high ecosystem concentrations in the coastal region south of Java. The advanced VPR technology permits to sample further offshore, to connect ITF, eddies, tuna spawning area to coastal upwelling.

Impact of climate change on Indian marine fisheries biodiversity

D. Sanna Durgappa[1] and Nitish Venkateswaralu

[1]Indian Institute of Science (IISc)

Abstract

In Indian marine fisheries biodiversity changes in interspecific relationships, in turn, can drive important local-scale changes in community dynamics, fisheries biodiversity, and ecosystem functioning, and can potentially alter large-scale patterns of distribution and abundance. Marine fisheries biodiversity in India encompasses all levels of complexity of life in the sea, from within species to across ecosystems. At all levels, marine fisheries biodiversity has naturally exhibited a general, slow trajectory of increase, punctuated by mass extinctions at the evolutionary scale and by disturbances at the ecological scale. In these current times, a synergy of human threats, including overfishing, global warming, biological introductions, and pollution, has caused a rapid decline in Indian marine fisheries biodiversity, as measured by species extinctions, population depletions, and community homogenization. In many cases, the importance of indirect effects of warming, mediated by changing species interactions, will be greater and less well understood—than direct effects in determining the community- and ecosystem-level outcomes of Indian climate change. The

consequences of Indian fisheries biodiversity loss include changes in ecosystem function and a reduction in the provision of ecosystem services. Indian fisheries biodiversity loss will continue and likely accelerate in the future, with potentially more frequent ecological collapses and community-wide shifts. However, the timing and magnitude of these catastrophic events are probably unpredictable. A better understanding of potential climate change impacts (scenarios) at both regional and local levels, the development of improved methods to quantify the uncertainty of climate change projections, the construction of usable climate change indicators, and an improvement of the interface between science and policy formulation in terms of risk assessment will be essential to formulate and inform better adaptive strategies to address the inevitable consequences of climate change. The paper illustrates how qualitative scenario planning provides opportunities to address the challenges of marine fisheries biodiversity conservation in a changing environment

Effect of climate variability on fish supply in West Africa: the case of small pelagics in West Africa

Piere Failler[1], Moustapha Deme and Djiga Thiaw

[1] Economics Centre for the Economics and Management of Aquatic Resources (CEMARE)

University of Portsmouth St. George's Building,141 High Street, Portsmouth, PO1 2HY, United Kingdom

Abstract

The paper presents an analysis over the last 30 years of the changes in fish supply of small pelagics in Senegal due to climate variability. It highlights how climate changes affect fish supply and therefore the nutritional patterns of coastal communities that rely on fish for animal proteins.

Impacts of climate and land-use changes on the fate of nitrogen in the Chesapeake Bay

Yang Feng[1], Marjorie Friedrichs, Hanqin Tian, Qichun Yang, Bo Tao, John Wilkin and Eileen Hofmann

[1] Virginia Institute of Marine Sciences, College of William and Mary, Gloucester Point, VA, USA

Abstract

Anthropogenic activities have produced unprecedented impacts on coastal regions over the past century. Together, climate and land-use changes have caused nutrient-enriched riverine flows to significantly impact estuarine biogeochemical cycles. In this study, we apply a land-ocean-ecosystem modeling system (DLEM-ROMS) to the Chesapeake Bay, the largest and most productive estuary in the U.S. By comparing model output with contemporary in situ and satellite-derived data, we demonstrate that our model successfully reproduces the hydrodynamic and biogeochemical fields in the Bay. In order to determine the effects of changing riverine inputs on the estuary, nitrogen budgets were compared for two DLEM river scenarios, including the contemporary scenario from 2001-2005 and the past century scenario from 1901-1905. This study will help quantify the impacts that changes in riverine inputs are having on estuarine and coastal environments.

Individual based modelling of red coral (*Corallium rubrum*) growth in response to environmental factors

Giovanni Galli, Lorenzo Bramanti, Cristina Priori, Georgios Tsounis, Sergio Rossi, Giovanni Santangelo and Cosimo Solidoro

Abstract

Corals are regarded as sensitive to climate change because they have narrow temperature tolerance ranges and, due to their carbonate skeletons, might be impaired by acidification; furthermore, being sessile, they cannot migrate quickly to more favorable places.

Yet the understanding of cause and effect relationships underlining coral response to the environment is still fragmentary. Suitable tools to derive reliable projection of ecological responses and impacts under expected environmental conditions are currently lacking. These issues were seldom addressed from a modelling perspective.

Mediterranean octocoral *Corallium rubrum* (or red coral) is an important constituent of coralligenous communities as well as an economically valuable species, it was subject to massive mortalities during summery heat waves and its sensitivity to acidification has been demonstrated in lab experiments.

In this study we developed a bioenergetic individual based model for Mediterranean red coral. The model simulates colony growth as a result of single polyps energy budget, is forced with food availability, flow conditions and seawater temperature and can be used to explore the organism functional response under current and future climate scenarios.

Impact of climate change on coral reef ecosystem of Andaman Islands

Grinson George[1], Rekha J. Nair[1] and Somy Kuriakose[1]

[1] Central Marine Fisheries Research Institute, Kochi- 682 018.

Abstract

Coral reef ecosystems are vulnerable due to increase in Sea Surface Temperature (SST) and extreme events such as cyclones and El Niño. There are several instances of massive coral reef bleaching in Andaman and Nicobar group of Islands (ANI). SST during night time is an important parameter for assessment of the thermal conditions inducing the bleaching. The estimation of monthly maximum mean using night time SST climatology retrieved using NOAA, AVHRR is used for generating reef health advisories to eliminate the effect of solar glare and reduce the variation in SST caused by the heating during day time. Threshold hotspot (HS) and daily heating week (DHW) values for a region are calculated. The occurrence of mass bleaching (1998 and 2010), mild bleaching (2002 and 2005) and non-bleaching (2011 and 2012) events in the coral reef regions around the Andaman Islands is examined seeking their relationship with NOAA AVHRR satellite derived SST to find out the relationship between the mass bleaching events and El Niño. Both Niño 3.4 and 3 indices are

examined and correlated with SST anomalies in the Andaman Sea. The rising temperatures are causing frequent cyclones in the Bay of Bengal (BoB). During 13–17 March 2011, the reefs in ANI suffered severe damage following a tropical cyclone in the BoB off Myanmar coast. The investigation exposed the vulnerability of the reefs to oceanographic features which generally remain unnoticed unless they directly affect the life or the property of coastal inhabitants. The wind tracks of cyclone were generated using weather research and forecasting (WRF) models which clearly indicated the passage of cyclone where reefs suffered damage. Recently, we have undertaken a survey on the major reef dwelling groupers, which are commercially in demand, to see the difference in their abundance due to reef bleaching. Earlier records point to the presence of 31 species of groupers (Family Serranidae) in Andaman waters. The present short study points to the presence of only 16 species from these waters indicating a change in the community structure of reef dwellers.

Monitoring of demersal fishes in the Azores (North-East Atlantic): a case study for addressing the issue of climate change?

Eva Giacomello[1] and Gui M. Menezes

[1] Centre of IMAR of the University of the Azores, Department of Oceanography and Fisheries, Horta, Portugal

Abstract

Fishing activities are of great importance to the economy of the archipelago of the Azores, accounting for 2% of the regional gross value added. The Azorean fisheries are mostly small scale and artisanal, multi-species and multi-gear, using hook and line gears and no trawl gear. In terms of economic value, demersal fishes account for more than 50% of the total annual ex-vessel price landed in the region. Most of demersal and deep-water fisheries are conducted on seamount-like features. Despite the artisanal nature of the fishery, exploitation rates are much intense and local severe depletion of demersal species have already been detected around some of the Azorean islands. The occurrence of multi-gear and multi-species fisheries and the geographically dispersed fishing grounds make the assessment of Azorean fisheries challenging, and in need of knowledge-based management.

With the aim of collecting data on demersal and deep water fishes, a monitoring survey has been established since 1995, consisting in an annual cruise throughout the Azores archipelago, and some cruises to other areas in the North-East Atlantic (as Madeira archipelago and seamounts off the Azores Exclusive Economic Zone). The standardized surveys use a long-line gear similar to that mostly in use by the local demersal fishing fleet, and provide data on fishing effort, depth, catches by species and some biological variables (as length, weight, sex, gonadal maturation stage). More recently, with the general aim of improving our understanding on seamounts and the quality of advice for management, a seamount in the central group of Azores has been declared as an area specifically earmarked for scientific research. Condor seamount is currently a protected area with the aim of providing, among other things, data on changes in fish community after cessation of intense bottom fishing for demersal and deep-water fish species.

Data obtained from monitoring cruises are useful to assess the ecological status of demersal fishes, evaluating changes in abundances, body size and other indicators over almost two decades of fishing. Moreover, exploring patterns of data such as distributional depth range, body size, sex-ratio along a longitudinal (i.e. western vs eastern group of Azorean islands) and latitudinal (i.e. Azores vs Madeira) gradient may shed light into their relationship with environmental variables (such as temperature). Inputs obtained from these analyses, in addition to specific information from Condor seamount (i.e. on fish recovery rates, food webs) may provide useful insights for addressing the issue of climate change.

Bacterial Biogeography along Stratified Water Columns in the Western Arctic Ocean

Dukki Han, Yoo Kyung Lee, and Hor-Gil Hur

Abstract

The Arctic Ocean is hydrographically complex and considered to be a double estuary with Pacific water entering through the Bering Strait and Atlantic water entering through the Fram Strait. A northward Pacific-origin current enters through the Bering Strait into the Chukchi Sea and intermixes with the northern Atlantic water that enters through the Fram Strait. However, the mixed currents are distinctive along depths of water column by their own water masses. Of the stratified structure of the Arctic water columns, surface mixed layer water (0-10 m) is strongly affected by melting sea-ice and river discharge during summer. Beneath the mixed layer which strongly affected by wind, the influx of Pacific water is significant, and the highest and the lowest temperatures indicate Pacific summer water and winter water, respectively. Atlantic water flows below Pacific winter water. An expedition of the IBRV ARAON took place in the Arctic Ocean during the summer of 2010. To investigate the hydrographic features of the bacterial variations in water columns, we categorized 16 collected water samples from the Arctic Ocean into distinctive water masses. Bacterial diversity, relative abundance, and community composition were determined based on a pyrosequencing approach, and then compared to water mass properties. Alphaproteobacteria (43.2%), Gammaproteobacteria (16.7%), Flavobacteria (13.7%), and Deltaproteobacteria (12.0%) were the most dominant classes of bacteria in all of the samples, and the relative abundance of these major populations represented the population dynamics of the bacterial communities in different water masses (from the euphotic to the sub-euphotic zone) in the Arctic Ocean. Furthermore, the relative abundance of Alphaproteobacteria and its subgroup, SAR11 group I, were significantly related to a depth change, suggesting that depth or environmental heterogeneity caused by depth change may play an important role in their population dynamics of this bacterium. Bacterial communities in the Arctic Ocean exhibit biogeographic patterns according to water mass types. The halocline layer between the Pacific winter water and Atlantic water exhibits the variation of bacterial community compositions, which may be influenced by the diapycnal mixing between Pacific winter water and Atlantic water.

Selection of indicators for monitoring within the Inuvialuit Settlement Region of the Beaufort Sea and Tarium Niryutait MPA

Carie Hoover [1], Sonja Ostertag, Joclyn Paulic, and Lisa Loseto

[1] Fisheries and Oceans Canada, Winnipeg, Canada

Abstract

This project combines indicators from different studies and scales in order to select useful indicators for (1) monitoring the coastal region of the Inuvialuit Settlement Region (ISR), and (2) satisfying the conservation objectives of the Tarium Niryutait Marine Protected Area (TN MPA). Management objectives for resources within the greater ISR include protecting and preserving Arctic wildlife, the environment and biological productivity. The TN MPA is made up of a series of three small coastal areas within the ISR. The MPA was established in 2010 primarily to protect the rights of local communities to harvest beluga and provide a hunting area free from oil and gas development including the prevention of future development). The conservation objective for the TN MPA is to conserve and protect beluga whales and other marine species (anadromous fish, waterfowl and seabirds), their habitats, and their supporting ecosystem. In order to meet the conservation objective of the TN MPA, some 82 indicators have been proposed for monitoring within six categories: ecosystem structure, ecosystem function, population structure of key species, heath of key species, physical and chemical environment, and noise and other physical stressors. This proposed list of indicators represents a complete ideal list for monitoring that has been deemed too large a task, both logistically and financially. For this reason, we are using the guidance of the management and conservation objectives, to select a subset of indicators to be evaluated using data from three separate research projects within the ISR study area. Each project attempts to address the objectives using a different approach to indicator assessment (ecosystem model indicators, regional stable isotopic analysis, and local observation) in order to address the variety of management questions within the ISR.

Crises for the Sundarbans mangrove ecosystem in Bangladesh: Threats, stressors and responses

Mohammad Mahmudul Islam

Sylhet Agricultural University, Sylhet, Bangladesh

Abstract

Using a case study approach this study will explore how different threats and stressors affect natural, social and governing systems of the Sundarbans mangrove ecosystem in Bangladesh and on the contrary, what are the roles of these systems in maintaining the sustainability of the fisheries resources of the Sundarbans. The result shows that natural systems of the Sundarbans have been subjected to conspicuous changes due to repeated exposure to climatic extreme events, reduction of freshwater supply due to upstream damming, climate variability induced-prolonged drought and intensive cold etc. On the other hand, over-exploitation of mother and undersized species,

particularly indiscriminate collection of the post larvae of shrimp and prawns cause recruitment overfishing in the Sundarbans. A number of threats and stressors in social systems also affect the sustainability of the fisheries resources and contributed to overfishing. Widespread poverty, high illiteracy, very heavy debt bondage with money lenders with high interest rates, vulnerability to different risks and shocks particularly sudden loss of life by tiger attacks and attacks by unlawful elements, to mention a few problems in social system. In particular the prevalence of money lenders cum traders who adopt monopolistic practices is blamed for over-exploitation of fisheries resources by many fishers interviewed. Governance failure is another driver that contributed to the over-exploitation of fisheries resources. For example rampant corruption of forest official in the exploitation process cause market failure and insist over-exploitation by illegal means. Insufficient budget, limited manpower, lack of incentives to the employees, poor organizational capacity, and top-down bureaucracy practice in decision making are perceived as main threats for the good governance of the Sundarbans. Finally this study submits that over-exploitation of fisheries resources of the Sundarbans is subjected to a complex set of natural, social and governance drivers, hence responses are required at multiple levels and scales.

Increased productivity and sea surface temperature results in better recruitment and spread of Indian oil sardine in Northern Indian Ocean

Rekha J Nair[1], Somy Kuriakose[1], Grinson George[1], P.U Zacharia[1] and A. Gopalakrishnan[1]

[1] Central Marine Fisheries Research Institute, Kerala, India

Abstract

Primary productivity (PP) and average sea surface temperature (SST) in Northern Indian Ocean increased during the last decade. The enhanced productivity had impacts on the Indian oil sardine (*Sardinella longiceps*) fishery in this region. During 1986, oil sardine from the southwest coast of India contributed to 7.8% of the total fish landings and 99 % of the oil sardine landings of India whereas, northwest coast comprising of Maharashtra and Gujarat contributed a mere 1.5 % to the total oil sardine landings of India. Averaged annual SST increased by 0.8°C along the southwest coast of India during the last 100 years. Slow decadal changes were noticed in the sardine fishery with contribution from the northwest increasing to 2% in 2005 and further to 4.6 % in 2012. Landings of oil sardine in the northwest region increased by over 31,548 tonnes during the period 1985-2012. This however did not cause any decrease in the landings in the southwest coast where landings increased from 1,20,575 tonnes in 1985 to 5,19,404 tonnes in 2012. Similarly, landings along the southeast coast comprising of the states of Tamilnadu and Andhra Pradesh accounted for only 3.7 % of the landings of oil sardine during 1985; this increased to 8.6% in 2005 and further to 16 % in 2012. SST showed an increase by 0.5°C during the last 50 years along this coast. Landings of oil sardine during the period 1985-2012 increased by over 1, 11,078 t. Similarly landings of oil sardine which was a meagre 1 tonne in 1985 in West Bengal which has risen to 85 tonnes in 2012. Congenial productivity and temperature conditions resulted in the enhanced potential and recruitment success of Indian oil sardine population in the area thereby increasing the production. Along this coast, SST showed an increase of 0.78°C during the last 50 years. The increase in production of oil sardine all

along the Indian coastline from 1,20,587 t in 1985 to 7,20,270 t in 2012 is a pointer to the beneficial effects of increase in PP and SST of small pelagics such as oil sardine.

OceanTuneIn –Oceanic Tunas as Indicators of Ecosystem Health

Maria-José Juan-Jordá, Hilario Murua, Haritz Arrizabalaga, Andy Cooper and Nick Dulvy

Abstract

Understanding to what extent human activities have altered marine biodiversity is an increasingly urgent societal challenge and of considerable scientific and policy concern. Our ignorance of the pressures upon and fate of marine biodiversity is, in part, because there are few synoptic global indicators to measure changes in marine biodiversity – particularly for exploited organisms in oceanic ecosystems. In my postdoctoral work I aim (1) to develop new indicators for measuring biodiversity change in oceanic marine ecosystems for the Atlantic, Pacific and Indian Ocean, using tunas, billfishes and sharks as sentinels of ocean health and (2) to develop management guidelines to determine how these indicators can be effectively used for improving management and conservation of oceanic ecosystems. This project will provide the tuna Regional Fisheries Management Organizations with a set of new products – a set of pressure, ecological state and threat indicators and a set of specific management guidelines, to assist them in the incorporation of ecosystem considerations in the management and conservation of tuna and tuna-like species. The new knowledge, tools, training, and collaborations generated in this project have the potential to support national and international policy commitments in light of the European Commission Marine Strategy Framework Directive and the 2020 Convention on Biological Diversity Aichi Targets.

Has fish harvesting altered biogeochemical cycling?

Lucas Kavanagh and Eric Galbraith

McGill University, Montreal, Canada

Abstract

Fish removal was the earliest major human influence on the marine environment and global fishing effort has increased by orders of magnitude since its ancient origins, depleting predatory fish biomass by as much as 90%. The full effects of this massive endeavour are poorly known, largely due to the lack of a constrained baseline. What did the ecological and biogeochemical dynamics of a pre-fishing ocean look like and how have they changed as a result of anthropogenic fish removal?

A severe depletion of upper trophic levels may result in a top-down ecological regime shift, manifesting in the form of trophic cascades and alterations to nutrient cycling and carbon export. Changes of this nature can be recorded in the sedimentary record through proxies such as fish remains, total organic carbon, 15N, and microfossil assemblages. This project searches for these biogeochemical effects of fish harvesting by compiling paleoceanographic data and comparing it to historical and archaeological records of fish harvesting. Hypotheses of potential effects and methods

of analysis will be discussed and preliminary results from the Peruvian Upwelling Ecosystem will be presented.

Exploring the effects that fish can have on biogeochemical cycles will help quantify the full impact of anthropogenic fisheries. This will aid in establishing pre-human baselines for ecosystem-based management and in the parameterization of upper trophic levels in ocean biogeochemical models.

Approaching model cross-validation against data from mesocosm experiments

Shubham Krishna and Markus Schartau

Abstract

The burning of fossil fuels is responsible for the observed increase of carbon dioxide (CO_2) in the atmosphere. This continuous increase enhances the net CO_2 flux from the atmosphere to the sea, thereby altering ocean biochemistry and likely affecting marine life. This CO_2-influx gradually decreases seawater pH, a process termed ocean acidification (OA). A continuous drop in pH and changes of the oceans' chemical state are expected in the future. Consequences of OA for marine flora and fauna are subject to ongoing research and are currently discussed. Investigations of OA effects on plankton were conducted with mesocosm, where enclosed water volumes were exposed to different CO_2 concentrations, e.g. Pelagic Ecosystem CO_2-Enrichment Studies. The central idea of our study is to use these mesocosm observations for systematic data-model syntheses. Our main objective is to assess whether ecosystem models can explain observed responses in plankton to variations in pH/CO_2 and temperature.

In our study we also wish to identify benefits and drawbacks of some recent approaches to marine ecosystem modeling. This will be achieved by systematic data-model comparisons and model parameter optimization. Markov chain Monte Carlo (MCMC) algorithms are used to estimate optimal model parameters such that misfit between model results and data are minimized. While comparing models, it is important to take in account model sensitivity to parameter change and induced uncertainty with the higher complexity. Number of parameters in a model increases exponentially with the number of model components. More complex the model, higher the number of model components and better the ability to reproduce observations, resolving more individual biogeochemical processes. But as it is said, “there are two sides to every coin”, therefore inclusion of complexity in a ecosystem model should be dealt carefully. If there is no data to constrain extra model component then it always leads to uncertainty. Hence, it is not sufficient to assess model performance on the basis of its ability to reproduce data, there should be a balance between added complexity and induced parameter uncertainty. Our primary technical task is to setup a mesocosm model environment in R. For this a wrapper function has been devised that allows us to make model calls from any R-script. Concurrently, we organized data from three mesocosm experiments, PeECE I, II, and III respectively. For our model environment we also prepared forcing files for single mesocosms.

On our poster first technical achievements and preliminary scientific results are presented. We show results from a model cross-validation against PeECE experimental data. Simulation results are

evaluated with respect to different parameterization of calcification. Also, our results reveal the feasibility of a single set of parameter values, apart from initial values, to show mesocosm differences within one experiment and between experiments. We also show model sensitivity to 2-D parameter change on our poster.

Effects of climate changes at multiple timescales on the fishing conditions of Grey Mullet (*Mugil cephalus* L.) in the Taiwan Strait

Kuo-Wei Lan[1], Ming-An Lee[1], Chang Ik Zhang[2], and Kuo-Tien Lee[1]

[1] Department of Environmental Biology Fisheries Science, National Taiwan Ocean University, 2 Pei-Ning Rd., Keelung 20224, Taiwan R.O.C.

[2] Faculty of Marine Production System Management, Pukyong National University, 559-1, Daeyeon 3-dong, Nam-gu, Busan 608-737 Korea

Abstract

Grey mullet (*Mugil cephalus* L.) is one of the most important commercial species of fish in the coastal fisheries of Taiwan. Since 1958, the catch of grey mullet has greatly fluctuated, exhibiting peaks of 2.54 million fish in 1980 and at bottom of 0.2 million fish in 2000–2004 in the coastal fisheries of Taiwan. It has been speculated that climate variability and rising SSTs caused by global warming have crucial impacts on the migration and catch rates of grey mullet; however, direct comparisons of long-term data on the migration numbers of grey mullet and climate change are scarce. In this study, we analyzed the long-term (1967–2009) records of grey mullet catch per unit effort (CPUE) in the Taiwan Strait (TS) to investigate the influences of climatic indices on the annual catch of grey mullet at multiple timescales. A wavelet analysis revealed that variations in climatic indices, namely the Pacific Decadal Oscillation (PDO), the Oceanic Niño Index, and sea surface temperatures (SSTs) might have affected the abundance and migration behavior of grey mullet in the TS in winter. The CPUE of grey mullet showed significant high correspondence with the annual PDO index ($R2 = 0.82$, $p < 0.01$). The results suggested that the PDO affects the migration of grey mullet, but that increases in SSTs are a more important influence on the decreased catches of grey mullet after 1980. Mean SSTs increased 1.01°C at the Chang-Yuen Rise in the TS from 1984 to 2009. The 20°C isotherms in the TS in the winter also shifted from 23–24°N in 1958–1978 to north of 25°N after 1998. The fishing grounds of grey mullet also shifted to the north following changes in the 20°C isotherm in the TS.

Decomposing the dynamics of an ETM in an energetic estuary.

Jesse Lopez[1] and António M. Baptista[1]

[1] NSF Science and Technology Center for Coastal Margin Observation and Prediction (CMOP), Oregon Health & Science University, Portland, OR

Abstract

Located in the Pacific Northwest of the United States, the Columbia River estuary features at least two estuarine turbidity maxima (ETM), or regions characterized by high concentrations of sediments. These ETM constitute important biogeochemical "hotspots" that contribute to many of the ecosystem services of the estuary. As part of a broader effort to model biogeochemical processes, we present the results of a numerical sediment model calibrated to the Columbia River estuary to study sediment dynamics. In particular, we investigate the physical processes leading to the generation of the Columbia River ETM including influence of density driven circulation, tidal asymmetries, lateral bays, intertidal flats, and the settling and resuspension of particles. We estimate the importance of each process by comparing the magnitude and timing of ETM events in each numerical simulation against those from a baseline run in realistic 3D domains. In agreement with previous idealized studies, preliminary results suggest that the Columbia River ETM requires the trapping processes of density driven circulation, tidal asymmetry of velocity and stratification, and particle resuspension due to erosion. However, the intertidal flats provide substantial source material for the ETM and have a large impact on the magnitude of the suspended sediments trapped in the ETM. Similarly, the presence of a source of resuspendable material is required to create the ETM, but contributes substantially to the magnitude and size distribution of suspended particles trapped in the ETM. These results contribute to our understanding of precise processes governing sediment dynamics in the Columbia River estuary and constitute a small, but important step in the development of a biogeochemical model.

Coral Traits: Indicators of Bleaching Susceptibility & Range Expansion Potential in a warming ocean

Toni Mizerek[1], Joshua Madin, Andrew Baird

[1] Macquarie University, Sydney, Australia

Abstract

Warm, tropical waters are home to hundreds of coral species. Sea surface temperatures at these low latitudes have increased globally and are projected to continue warming over the coming decades. Susceptibility to this thermal stress varies by species but survival through these changing conditions may be facilitated by species' characteristics that promote persistence as waters warm over the long term and also through immediate stressors like bleaching events. To understand how different species may be able to cope with the temperature increase on different time scales, I evaluated characteristics of coral species using the Coral Traits Database (coraltraits.org). Species' traits, which have often been applied in plant ecology studies, are used as surrogates for understanding relationships within communities or ecosystems. In particular, I examined the relationships between coral traits that infer resilience to bleaching and/or those that may facilitate changes in distributions.

As an immediate response to thermal extremes, corals may bleach (expel their symbiotic algae), some species more severely than others. Any degree of bleaching can impact coral health, potentially lead to death and may devastate coral reef ecosystems overall. Species-specific post-bleaching coral surveys that measured categorical responses to bleaching events (normal, pale, bleached, dead) were modeled as a function of coral traits hypothesized to influence bleaching

susceptibility. The best predictors of the degree of bleaching include coral growth form; species' corallite size (the hard skeleton of a single polyp); phylogeny of the symbiotic algae; and mode of algal symbiont transmission (in larvae or not). This suggests that corals with specific combinations of these traits are more likely to withstand extreme temperatures in the short term.

Over longer time periods, species capable of distribution shifts may be more likely to persist through significant environmental change. One obstacle to a pole-ward shift into cooler water is the ability of species to settle and survive in habitats beyond reef growth. I evaluated differences in species' traits for corals that live both on and beyond reef throughout the Indo-Pacific in comparison to those that are found only on reefs. Those species found pole-ward of reef growth generally shared a common set of traits including: large depth range, tolerance to turbid water and certain growth forms, especially encrusting and massive.

These results suggest that evaluating various coral traits (reproductive, morphological, phylogenetic, etc.) can support our understanding of species-specific responses to warming waters on different time scales. Given that coral traits are becoming readily available, this trait-based approach provides enormous potential to predict responses to impacts of a variety of major threats coral reef ecosystem health globally, identifying which characteristics may allow certain species to cope – or not – with changing conditions.

Impact of stratification on timing and magnitude of phytoplankton bloom in southwestern the East/Japan Sea: Application of 1D GOTM-ERSEM to the Ulleung Basin

Yuri Oh, Chan Joo Jang and Momme Butenschön

[1] Korea Institute of Ocean Science & Technology, Ansan, South Korea

Abstract

Ulleung basin (UB) located in southwestern part of East Sea (Japan Sea) is considered having a high primary productivity due to nutrient supplements such as wind-driven upwelling, current transport, eddy-induced upwelling. We applied a vertically one-dimensional biological model (1D GOTM-ERSEM) to Ulleung basin focusing on timing and magnitude of phytoplankton bloom. To investigate impact of stratification on timing and intensity of phytoplankton bloom in the Ulleung basin, three different temperature and salinity dataset were assimilated in GOTM. When MLD in winter is relatively shallow, spring bloom tends to occur earlier (in Feb.) by two months, compare with observations. The magnitude is smaller than the observations. In contrast when MLD in winter is relatively deep, timing of spring bloom and intensity become more realistic. This represents the stratification contributes to determining timing of spring bloom and magnitude of spring bloom in the Ulleung Basin.

Seasonal sinking fluxes of trace elements in a coastal system in Western Cantabrian Sea (Bay of Biscay)

Natalia Ospina-Alvarez[1,2] and Ricardo Prego[1]

[1] Marine Research Institute (IIM-CSIC). 36208 Vigo, Spain.

[2] University of Warsaw, Faculty of Chemistry. 02-093 Warsaw, Poland.

Abstract

It is widely known that estuaries are natural traps for trace elements, however, dynamics of those entrapment process still have to be studied and understood. In this study, vertical fluxes of particulate metals (Al, Cd, Co, Cr, Cu, Fe, Ni, Pb, and V) were studied in the Ria of Barqueiro (Galicia, NW Iberian Peninsula). Sampling was carried out from Jan. 2008 to Jan. 2009 at the middle ria (20 m depth), by means of a multitrap collector system anchored to the sea-bottom during a 24 h period. Additionally, physicochemical variables of the water column, chlorophyll and primary production were measured. Seasonal description was done following the oceanographic periods previously defined for the Ria of Barqueiro according to its thermohaline properties, nutrient concentration and phytoplankton biomass: spring (Apr, May, Jun), summer (Jul, Aug, Sep), autumn (Oct, Nov), winter (Dec, Jan, Feb, Mar). The suspended particulate matter revealed a seasonal decreasing in the sedimentation, with the highest values during winter (56 $g \cdot m^{-2} \cdot d^{-1}$) and the lowest during autumn (4.6 $g \cdot m^{-2} \cdot d^{-1}$). Sinking fluxes were 0.56±0.90 $gAl \cdot m^{-2} \cdot d^{-1}$, 2.04±1.49 $\mu gCd \cdot m^{-2} \cdot d^{-1}$, 0.11±0.14 $mgCo \cdot m^{-2} \cdot d^{-1}$, 2.87±4.97 $mgCr \cdot m^{-2} \cdot d^{-1}$, 1.79±1.08 $mgCu \cdot m^{-2} \cdot d^{-1}$, 0.48±0.55 $gFe \cdot m^{-2} \cdot d^{-1}$, 1.57±2.74 $mgNi \cdot m^{-2} \cdot d^{-1}$,1.27±1.41 $mgPb \cdot m^{-2} \cdot d^{-1}$, and 0.75±0.91 $mgV \cdot m^{-2} \cdot d^{-1}$. A high variability was observed in the seasonal behaviour of the studied metals, with the highest values during winter for Al, Cu, Ni and V, during spring for Co, Fe, and Pb and during autumn for Cd and Cr. Lithogenic particle fluxes (Al, V) were higher during winter, associated to the increase of sedimentation due to the rainy season.

This study is a contribution of the INTERESANTE (CICYT ref. CTM2007-62546-C03/MAR) and MITOFITO (MINECO ref. CTM2011-28792-C02) projects. Dr. Ospina-Alvarez gratefully acknowledges support by a post-doctoral grant from the AXA Research Fund (2nd wave-2012).

Monitoring anthropogenic threat to mangroves along Central West Coast of India: a holistic approach

Rajani Panchang

Agharkar Research Institute (MACS-ARI), Pune, INDIA

Abstract

Kundalika and Vasishthi are two major estuaries draining the central west coast of Maharashtra, a highly developed state in India. Both estuaries house luxuriant mangroves. Unfortunately, these estuaries have also been means for discharging industrial effluents, ever since the establishment of important industrial development corporations in their vicinities. Serious concerns have been raised by NGOs and local population over dwindling fish resources in both the estuaries, rendering the fishing profession defunct. Whilst authorities refrain from assigning the environmental status of these estuaries despite timely water quality monitoring, the present work documents evidences for deterioration in the environment, due to rampant human intervention.

The dense, sanctuary-like mangroves of the Kundalika estuary are the only ones in the State ear-marked by the government for conservation. However, subsequent field visits reveal rampant suction-sand mining in the channel of the estuary in its middle and upper reaches. Over a kilometre long stretch of the mangrove mudflats in the upper reaches of the estuary have been dredged and reclaimed and are being used for stacking and loading illegally mined sand and as landing/parking of suction sand dredges. This is detrimental and causes irreversible damage to the fertile breeding grounds of this estuary, which is the major cause of collapse of the fish catch in the estuary. However, these postulations are being verified using downcore foraminiferal signatures to understand impact of human-climate interaction in the estuary over the past few centuries.

Proliferation of foraminiferal and diatom species tolerant to heavy metal toxicity in the Vasishthi estuary suggests heavy metal toxicity in the environment. The geo-accumulation index and enrichment factors are suggestive of significant Cu enrichment and strong pollution thereby in the estuary. Though each of the remaining heavy metals, viz. Mn, Co, Ni, Cr, Zn, Pb and Cd show moderate levels of contamination, their combined degree of contamination is indicative of extremely strong levels of toxicity in the estuarine environment. The geo-accumulation index is suggestive of non-anthropogenic sources of pollution. High heavy metal concentrations in the estuary could also be the cause of proliferation of oyster species, *Saccostrea cucullata*. Field observations suggest physiological impairment of mangroves due to biofouling, due to which their capacity to accrue sediments is being lost. Thus, biofouling by *S. cucullata* is not only a major threat to the mangrove forests in the Vasishthi estuary, but also to the tidal flats which are a haven for diverse benthic community, organic carbon sinks and natural adsorbents of pollutants.

Extensive biofouling on mangroves in the Vasishthi estuary and sand-mining in the Kundalika are the major reasons for destruction of these mangroves. A holistic approach exhibits how different trophic levels in these estuaries have been impaired and demand management and restoration.

The ugly face of flood events

Ravindra Rattan

Abstract

Climate change has contributed to a rise in extreme weather events. Its effects are higher temperatures, changes in precipitation patterns, rising sea level, increase weather volatility and more frequent weather-related hazards, thence, pose risks for agriculture, food, and water supplies. Extreme natural disasters and an increase in global temperature will severely reduce the food production and will have severe impact on livelihood in Pacific islands and called for urgent measures to adapt to expected losses. Pacific Island countries are spread over a vast area of the Pacific Ocean, occupying an area over 30 million km^2. Smallness, remoteness and vulnerability are the major problems affecting the Pacific Island Countries. The heterogeneous Pacific Island countries are particularly vulnerable to the effects of climate change and thus are exposed to more frequent natural hazards, such as tropical cyclones, flash floods, and droughts. The impacts of climate change on food and livelihood security is not uniformed because of the characteristics of PICT's, which spans

many different ecological, geographic, and meteorological zones. In Social Science ideas about vulnerability to natural disasters have emerged in the past three decades. To adjust, adapt to cope or if necessary to recover from adverse events is a big challenge in Pacific Island countries like Fiji Islands. Maintaining the sustainable livelihood pattern for every households, albeit being poor or rich is one most commonly advocated sustainability strategies in response to extreme flood events in Nadi area, Fiji. A tourist and agriculture town with an area of 8 km² and having approximately 70000 people (10000 households), Nadi has been prone to flooding over the last fifteen years and it has been hit by 9 severe flooding from 1999. The nation was jolted in motion in 2012 when it was hit by two consecutive floods that was January and March flooding. Therefore, to understand and address this problem, one developed a framework which combined the sustainable livelihood framework and food security dimension framework. To understand one particular extreme event in the PICT´s, therefore, a case study was conducted focusing on the extreme flood events of January, 2012 and March, 2012 flooding and its impacts on food and livelihood security in Nadi. We use the combined sustainable livelihood and food security framework to prove that livelihood and food in-security does exists in Nadi, Fiji islands, even for a short time (transitory) during the flood until it is nigh to recovery.

Exploring spatial variability in the controls on the spring phyotoplankton bloom.

Tyler Rohr

Abstract

Oceanic uptake of anthropogenic CO_2 is a predominant factor in mitigating a dangerous rise in atmospheric CO_2 levels, and the Southern Ocean accounts for a disproportionately large fraction (~1/3) of total oceanic uptake. Faced with a changing climate, understanding the controls on phytoplankton ecosystem dynamics in this region is critical to better understanding the biological pump, the air/sea CO_2 flux, and long term variability in CO_2 storage. 900 years of high temporal resolution model output from the Community Earth Systems Model are used in tandem with historical observational satellite data to study and quantify the spatial variability in the controlling mechanisms on the spring phytoplankton bloom in the Southern Ocean. Qualitative and quantitative discrepancies between population specific growth rates and cell specific division rates are studied in relation to bloom size and phenology to provide insight into which biological, trophic or physical controlling mechanisms dominate regionally. Moving pole-ward, results indicate a substantial increase in bloom magnitude and significant delay in bloom phenology. Further, results suggest the possible existence of a spatial transition from the dominance of a 'Top-Down' to 'Bottom-Up' control on bloom dynamics. Spatial variability in the relevant physical processes (sea ice, mixed layer depth, etc.) appears to play a critical role in mediating this transition. As climate driven alterations moderate these physical processes understanding the spatial variability in their role controlling bloom dynamics will help provide predictive insight to global oceanic carbon storage.

Modeling mercury cycle dynamics in a temperate lagoon (Marano-Grado, Italy)

Donata Melaku Canu, Ginevra Rosati and Cosimo Solidoro

Abstract

The Marano-Grado lagoon (Northern Adriatic Sea, Italy) is one of the best preserved wetland environments in the Mediterranean area. It offers shelter to many bird species and provides significant ecosystem services which sustain several economic activities. The lagoon was subjected to long term mercury loadings mainly coming from two anthropogenic sources: a cinnabar mine and a chlor-alkali plant. Although these activities ceased years ago, the lagoon, as well as the nearby Gulf of Trieste, still exhibits high mercury concentrations in water, sediment and biota due to environmental persistence of mercury. In aquatic environment mercury undergoes several transformations and can be found primarily in three chemical species present in a variety of both inorganic and organic complexes: elemental Hg (Hg^0); divalent ionic Hg (HgII), and methylated Hg (MeHg). The latter is the more bioavailable species and tends to bioaccumulate and biomagnificate through trophic nets.

Understanding the relative importance of transport, transformation and bioaccumulation processes is crucial for the ecosystem based management of the lagoon. With this aim, an integrated modeling approach has been adopted to estimate fluxes of mercury species in the lagoon and between the lagoon and its surrounding systems (Adriatic Sea, atmosphere, deepest sediments and watershed). Two mercury models developed by US EPA and publicly available have been implemented to complement the experimental knowledge and to perform mass balance and scenario analysis. Data characterising the biogeochemical cycle of mercury in the Marano-Grado lagoon have been gathered and the lagoon has been represented as a six box system, interacting with its boundaries. Model parameters have been derived from site specific data, when available, or from parameters related to similar environments, as reported in literature.

The SERAFM model was implemented describing the lagoon at steady state. Given HgT concentrations in sediment, the model computes concentrations of mercury species in different environmental compartment, biota included, driven by hydrological characteristics, other environmental data, and mercury process parameterization. The model also allows the user to estimate wildlife and human risk related to MeHg bioaccumulation. The WASP model was implemented representing the lagoon as a dynamic six connected box system. Time variable water fluxes between the six boxes and with the Adriatic Sea have been introduced, based on a high resolution hydrodynamic model results. Variable river discharge and mercury concentration and at the boundary systems are taken into account. This model does not consider the living compartment but it can represent mercury species dynamics and seasonal trends. Models results have been compared to a small validation data set.

Our results point out that the Gulf of Trieste gives currently the main contribution to Hg concentration in surface water and that sediment represents a secondary source of Hg and MeHg contamination. Rivers and atmospheric deposition loads do not have remarkable effect on concentration of HgT, although atmospheric deposition affect Hg^0 content. MeHg on average, account for the 0.77% of THg in water and the 0.09% in surface sediment. Hazard analysis indicates that children and piscivorous wildlife could be at risk.

Impacts of coastal ocean acidification in the Baltic Sea region: Zombie forams and biomarkers

Petra L. Schoon[1], Laurie Charrieau, Helena Filipsson, Karl Ljung, Emma Kritzberg, and DISCO partners

[1] Department of Geology, Lund University, Lund, Sweden

Abstract

Since the industrial revolution about half of the emitted anthropogenic CO_2 has been absorbed by the world oceans. This has caused a shift in the ocean carbonate chemistry and a decrease in seawater pH, a process referred to as ocean acidification. The effects of ocean acidification are, however, not uniform. Due to the higher solubility of CO_2 in colder water, it is predicted that the impact of ocean acidification on marine life is larger at higher latitudes. Furthermore, in coastal oceans additional environmental stressors can play a large role, such as salinity variations, deoxygenation as a result of eutrophication, higher run-off due to increased erosion and consequential higher nutrient load and changes in circulation patterns. These processes will contribute to a lowering of pH and a lowering of the carbonate saturation state. The consequences of the combination of these environmental stressors on coastal micro-organism communities are, however, not yet known, but are expected to cause major changes in biogeochemical cycling and ecosystem dynamics.

To gain a better understanding of how the benthic ecosystem is responding to changes in pH in a coastal area, the DISCO (Drivers and Impacts of Coastal Ocean Acidification) project integrates results from benthic foraminiferal communities with high-resolution biomarker records as well as hydrographic data from nine sites sampled along the Swedish coasts. In the Baltic Sea region the seawater pH is low enough to dissolve calcium carbonate and to affect shell preservation of calcifying organisms. Our preliminary results reveal substantial dissolution of benthic foraminifera. Furthermore, from two sites we found living foraminifera of which their shells were completely dissolved. How long these so-called zombie foraminifera can survive under these circumstances remains uncertain.

To further study the separate effects of the various environmental stressors, we also focus on the distribution and stable carbon isotope patterns of certain biomarker lipids. Biomarkers are fossil chemical compounds, which have a biological origin and can be related to a specific group of organisms or to their metabolic pathways. We will target specific marine and terrestrial biomarker lipids derived from different sources (i.e. organic matter from higher plants, marine algae, bacteria, and archaea), which will provide us information on the spatial and temporal climate variations in the Baltic Sea region for the last ~200 years. By comparing the results obtained from the benthic foraminifera with that of the biomarker records from the same sites we will be able to assess the different responses within the micro-organism community. This is of paramount importance, because many micro-organisms are important players within the global carbon cycle and stand at the basis of the marine food web. A change in the biogeochemical cycling due to coastal ocean acidification may therefore have dire consequences for the entire ecosystem, such as lower biodiversity and, in turn, threaten seafood resources.

Redistribution of anchovy *Engraulis japonicus* wintering stock under climate change scenarios in the Yellow Sea

Xiujuan Shan[1] and Yunlong Chen

[1] Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Qingdao, China

Abstract

With the increasing effects of climate change and human activities on marine ecosystem, the dynamics offishery resources are greatly changed. As the key species in food web of the Yellow Sea, anchovy *Engraulis japonicus* plays a critical role in fishery community, as well as to marine ecosystem. In the present study, based on the fishery survey data in the central and southern Yellow Sea, the redistribution of anchovy was evaluated using a modified dynamic bioclimate envelope model under climate change scenarios. A habitant suitable function, consisting of SST and sea surface salinity (SSS), was used to demonstrate the impacts of environment factors on the wintering anchovy stock; four climate change scenarios were analyzed, including RCP2.6, RCP4.5, RCP6 and RCP8.5, these came from Geophysical Fluid Dynamics Laboratory (GFDL) CM2.0, and represented the low, relative low, modest and the highest emission scenarios; the resource barycenter was used to evaluate the reaction of wintering anchovy to different climate change scenarios. The wintering anchovy stock showed the obvious northward trend, reached as much as to 2.5-2.7°in the next 30 years. The average speed of shift to northward could be 0.09°per year. There were no significant differences ($P>0.05$) among the four climate change scenarios. In the sensitivity analysis, the scale constant k was not sensitive to the redistribution of anchovy stock, while the intrinsic rate of population increase r was closely related to its redistribution.

Ocean warming and acidification scenarios in the northern Bay of Bengal, Bangladesh

SM Sharifuzzaman[1], MS Hossain, SR Chowdhury and S Sarker

[1] Institute of Marine Sciences & Fisheries, University of Chittagong, Chittagong, Bangladesh

Abstract

Historical sea-surface temperature (SST) and seawater pH data, which were obtained from the National Oceanographic Data Center, were analyzed using ocean data view and ArcGIS tools to determine the state of warming and acidification of marine ecosystem Bangladesh in the northern Bay of Bengal. The temporal trends indicate that SST has gone up during the past few decades, i.e. an average increase is recorded from 28.39^{o}C (1970-1979) to 28.86^{o}C, 29.31 and 29.39^{o}C over the years of 1980-1989, 1990-1999 and 2000-2010, respectively. In case of pH, the average value has been found to be declining, i.e. a decrease is noted from 7.8 (1970-1979) to 7.6 and 7.3 over the years of 1980-1989 and 1990-1999, respectively. Incidentally, the rising temperatures and lowering pH of ocean can have adverse effects on marine life (i.e. declining fisheries resources), and ecosystem processes and services. This would directly affect the livelihoods of millions of coastal poor people. However, most of these issues are poorly understood and virtually nothing has been

studied in Bangladesh regarding climate change impacts across marine systems. Therefore, an improved monitoring programme is essential to recognize the current and future costs of ocean warming and acidification in Bangladesh.

For establishing a model of evaluation the ecosystem services of open oceans

Zhonghua Shen[1], Taro Oishi, Hisashi Kurokura, Nobuyuki Yagi and Ken Furuya

[1] Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan.

Abstract

Evaluation of the economic value of ecosystem services (ES) has being widely applied to understand the multiple benefits provided by ecosystems. As an important component of global ecosystem, open oceans are facing more and more challenges today not only on fisheries, but also on implementations of geoengineering for mitigating climate change and exploitations of ocean floor resources. However, studies regarding evaluation of open oceans' ES are few and almost all of them evaluating the ES of open oceans by "replacement cost methods (CM)". As a shortcoming of CM method, non-use (including legacy, existence & altruism) value cannot be revealed, and this hence causes a defective valuation results. In order to get the comprehensive value of open oceans, "conjoint analysis (CA)" method could be employed. However, as a necessary condition for using the CA method, amount of each ES by regions must be known. At present, although the total amount range of most ES are known, its accuracy is not sufficient to apply regional ecosystem-based management. The other research groups, in research project titled "The New Ocean Paradigm on its Biogeochemistry, Ecosystem, and Sustainable Use (NEOPS)", is collecting kinds of natural scientific data in the North Pacific. The ultimate goal of this study is to use these collected data to establish a model of evaluating the ecosystem services based on CA method.

As the first step before we get the total data from the natural science group. We conducted pre-tests research by using conjoint analysis to obtain the "willingness to pay (WTP)" of general Japanese citizen. In the questionnaire survey, the respondents were told that an assumed geoengineering project (Fe fertilization) will be conducted in the open oceans. Through this project three main services of open oceans (CO_2 absorption, food production, and water purification) will be improved. After collecting the answers, we analyze the raw data with the "choice-based conjoint analysis" based on logit model.

Through the first survey, we elicited Japanese respondents' marginal WTP (MWTP) for three main ES of open oceans. Furthermore, we found variation across different prefecture in WTP trends for the three OPES, implying the influence of traditional food culture, mass media and natural hazards. Differences in WTP trends were also found to depend on income level and gender. Due to the second survey, we detected the relation between WTP and the respondents' educational level. Furthermore, we calculated the discount rate of WTP for the ES of open oceans between present and future, which should be considered into decision-making process.

Preliminary multiproxy surface air temperature field reconstruction for China over the past millennium

Feng Shi[1], Bao Yang and Lucien Von Gunten

[1] Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

Abstract

We present the first millennial-length gridded field reconstruction of annual temperature for China, and analyze the reconstruction for spatiotemporal changes and associated uncertainties, based on a network of 415 well-distributed and accurately dated climatic proxy series. The new reconstruction method is a modified form of the point-by-point regression (PPR) approach. The main difference is the incorporation of the "composite plus scale" (CPS) and "Regularized errors-in-variables" (EIV) algorithms to allow for the assimilation of various types of the proxy data. Furthermore, the search radius is restricted to a grid size; this restriction helps effectively exclude proxy data possibly correlated with temperature but belonging to a different climate region. The results indicate that: 1) the past temperature record in China is spatially heterogenic, with variable correlations between cells in time; 2) the late 20th century warming in China probably exceeds mean temperature levels at any period of the past 1000 years, but the temperature anomalies of some grids in eastern China during the Medieval climate anomaly period are warmer than during the modern warming; 3) the climatic variability in the eastern and western regions of China was not synchronous during much of the last millennium, probably due to the influence of the Tibetan Plateau. Our temperature reconstruction may serve as a reference to test simulation results over the past millennium, and help to finely analyze the spatial characteristics and the driving mechanism of the past temperature variability. However, the lower reconstruction skill scores for some grid points underline that the present set of available proxy data series is not yet sufficient to accurately reconstruct the heterogeneous climate of China in all regions, and that there is the need for more highly resolved temperature proxies, particularly in the Tibetan Plateau.

Potential effects of climate change-induced alterations to trophodynamics along the western Antarctic Peninsula

Paul M. Suprenand and Cameron H. Ainsworth

Abstract

In the present study we predicted changes that may occur to the western Antarctic Peninsula's marine ecosystem according to predicted alterations in water circulation changes from predicted westerly wind intensification, nutrient upwelling, circumpolar deep water upwelling, and decreased sea-ice extent as it effects primary productivity, as well as ocean acidification-related reductions in thecosome pteropod productivity, individually and together, using a series of linear forcing function scenarios in an Ecopath with Ecosim model to anticipate their effects to the marine ecosystem over the next 40 years. We focused on predicting changes in primary and secondary production, because these trophic levels are likely to cause significant alterations to the entire western Antarctic

Peninsula's marine ecosystem; in particular changes in biomass, ecosystem biodiversity and/or mean trophic level through positive or antagonistic interaction effects. Biomass was observed to decrease more severely in co-occurring primary production and thecosome productivity forcing-functions scenarios, than would have been predicted based on individual scenario outputs. This would indicate the possibility of synergistic dynamics in the ecosystem. Organismal groups in the model that emerged as losers or winners in the climate change scenarios corresponded to predicted ecosystem shifts. For example, the model indicated that with a decline in the biomass of krill biomass, salp biomass would increase. Pteropods, historically included in aggregated planktonic groups within other Ecopath with Ecosim models, when considered as individual species in the present study, demonstrated significant influences to the marine ecosystem, particularly in environmental forcing functions that considered ocean acidification's effects to their productivity.

Modelling interaction of physical and ecological processes in Lake St. Lucia with respect to conservation and management of the system

Katrin Tirok, Julia Schoen, Vulindlela Zikhali, Ursula Scharler and Derek Stretch

[1] University of KwaZulu-Natal, School of Life Sciences/School of Engineering, Durban, South Africa

Abstract

Lake St. Lucia is one of Africa's largest estuarine lakes and is part of the iSimangaliso Wetland Park, a UNESCO World Heritage site. The system is an important source of biodiversity and plays an important role as a nursery ground for fish and prawn which are sustained by a diverse and productive planktonic and benthic food-web. Lake St. Lucia is a large and shallow system where wind driven currents and waves are the key processes for the exchange of water between individual lake basins and for the resuspension and transport of sediment and organic material. These physical processes influence biological processes such as primary production, benthic-pelagic coupling and dispersion of organisms. We study the interaction of ecological and physical processes with the help of mathematical models. We simulate wind driven currents and waves with a hydrodynamic spatially explicit model of Lake St. Lucia which is coupled with a model of microalgal dynamics and their grazers using the model environment Mike21 (Danish Hydraulic Institute). Using such a coupled spatially explicit approach allows for an integrated physical, chemical and biological description and modelling of the St. Lucia Lake system, providing an excellent basis for predictions on its behaviour under certain environmental conditions and management scenarios. In particular, we study the effects of resuspension on ecological dynamics at different scales in Lake St. Lucia and possible re-colonisation patterns of the lakes following extreme conditions. Results of our research will provide important information for conservation and management practitioners and will help to sustain the ecosystem goods and services of the St. Lucia lake system.

The influence of biomass on the habitat preference of three small pelagic fish species in the southern Benguela

Nandipha Mhlongo[1], Dawit Yemane, Janet Coetzee

[1] Fisheries Management Branch, Department of Agriculture, Forestry, and Fisheries, Cape Town, South Africa ; Marine-Research Institute (MA-RE), University Cape Town, Cape Town, South Africa

Abstract

Environmental factors that govern habitat preference and impact on fisheries resources can be determined by linking prevailing environmental conditions to the abundance and distribution of individual species. Spatially-explicit estimates of the abundance of anchovy (*Engraulis encrasicolus*), sardine (*Sardinops sagax*) and round herring (*Etrumeus whiteheadi*) during the adults life history stage were combined with oceanographic data to reveal the habitats utilized by these three species at different biomass levels in the southern Benguela upwelling ecosystem. These species are of great socio-economic and ecological importance to the region and are vulnerable to population fluctuations in response to environmental variability. To understand the preferred environmental envelop of each species and how habitat usage is affected by biomass, a single parameter quotient (SPQ) method with randomization was used. The analysis was conducted using three subsets of fish density data; firstly including data from a period when the total combined biomass of small pelagic fish was high, secondly using data from a period of average biomass and thirdly using only data from a period when the combined biomass was low. Results indicated variable habitat use by these small pelagic species across gradients of environmental variables. During low and high biomass levels anchovy preferred slightly different bottom temperatures ranging between 16.0-19.0°C and 15.0-18.5°C, respectively. Sardine on the other hand preferred a broad range of warmer temperatures (15.5-20.0°C) at high biomass levels and a narrower range of cool temperatures (15.5-18.5°C) during the low biomass period. Compared to sardine, anchovy occurred over a broader range of depths (15 to 65 m) at high biomass levels. This basic biological information is an essential step towards understanding habitat partitioning and population responses, and hence the role that environmental change may play in regulating the distribution, abundance and hence management of these species.

Tracing the composition of dissolved organic matter by fluorescence analysis in mesocosms of Sanggou Bay, North China

Xiaona Wang[1], Ying Wu[1], Zengjie Jiang[2], Qianqian Ma[1], Jing Zhang[1], Sumei Liu[3]

[1] State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, PR China

[2] Key Laboratory for Sustainable Utilization of Marine Fisheries Resource, Ministry of Agriculture, Yellow Sea Fisheries Institute, Qingdao 266071, China

[3] Key Laboratory of Marine Chemistry Theory and Technology Ministry of Education, College of Chemistry and Chemical Engineering, Ocean University of China, Qingdao 266100, PR China

Abstract

Aquacultural activity has developed rapidly, especially in China. The potential contribution of aquaculture to the global carbon cycle is not well understood. Sanggou Bay, which is dominated by

aquaculture systems, was chosen as the site for this study characterizing the composition and abundance of dissolved organic matter (DOM) and its potential link to CO_2 dynamics. Field incubation experiments of eight mesocosms containing various aquaculture species were carried out (6 days) in July 2013 to explore the impact of aquaculture species on DOM composition. The dissolved organic carbon (DOC) and chromophoric dissolved organic matter (CDOM) showed increasing trends, suggesting the release of DOM by plankton and aquaculture species. Parallel factor analysis (PARAFAC) was applied to identify the independent components of the excitation–emission matrix spectra (EEMs), and four components were identified: two humic-like components (C1, C4) and two protein-like components (C2, C3). The correlation between the aquaculture species present and the concentrations of humic-like components indicated that seaweeds and bivalves play important roles in the production of humic-like matter. The variation in the protein-like components and chlorophyll a demonstrated that plankton contributed to the variation in the protein-like CDOM in this study. The significant increase in protein-like matter suggested that it is likely that the carbon sink flux in the Sanggou Bay aquaculture systems has been overestimated.

Verification of flood risk areas based on climatic and geomorphological conditions in central highlands and coastal lowlands of Sri Lanka

Ashvin Wickramasooriya

Department of Geography, University of Peradeniya, Peradeniya, Sri Lanka

Abstract

Flood is one of the common natural hazards that is experiencing specially in central highlands and coastal lowlands of Sri Lanka. Floods have been creating a significant influence on environmental as well as socioeconomic like damage and loss of properties, loss of lives, degradation of cultivated lands, etc. The intense rainfall is the key factor influence on floods. However, some other factors like geomorphological features, siltation, landuse pattern and some human activities are also contribute to create floods. According to geomorphological and the landscape setting of Sri Lanka, many rivers like Mahaweli, Kalu, Kelani, Walawe and Gin rivers start from the central highland and flow through the coastal lowland and fall into sea in different places. Many occasions in the past, these rivers affected by coastal floods, river floods and flash urban floods during Southwest and Northeast monsoon periods from May to August and December to January. Other than getting an intense rainfall, siltation on river beds due to soil erosion, deforestation, chena cultivation, alteration of flood plains by natural and human activities also contribute to record many number of floods in the country. These factors were concerned for the preparation of initial flood risk zonation maps for the study area. Thematic maps were produced using satellite imageries, climatic data, landuse data, geomorphological data, etc. Geographical Information Systems (GIS) techniques and Multi Criteria Decision Analysis methods were applied to analyze and to demarcate the flood risk buffer zones within central highlands and coastal lowlands.

Primary productivity and its interannual variability in the East Sea, 1998-2007

Joo-Eun Yoon[1], Young Baek Son and Sinjae Yoo

[1] Marine Ecosystem Research Division, Korea Institute of Ocean Science & Technology, 787, Haeanro, Ansan, 426-744, Korea

Abstract

We investigated the interannual variability of primary production in the East Sea for the 10-year period from January 1998 to December 2007. Primary production was calculated from satellite ocean color data using a local primary production algorithm for the East Sea. To identify the spatio-temporal patterns of primary production, empirical orthogonal function analysis was applied. Based on this, the East Sea was classified into several sub-regions using K-means clustering method. The primary productivity of each sub-region showed characteristic seasonal and interannual variability. The time series of primary productivity of each sub-region were compared with physical factors (wind stress, mixed layer depth, photosynthetic available radiation and volume transport of the Tsushima Warm Current) and climate indices, such as the Multivariate ENSO Index, the Siberian High Index and the East Asian Winter Monsoon Index. The seasonal and annual primary productivity in each sub-region show different relationships with physical forcing and climate indices. Here we discuss how the variability of primary production in the East Sea is linked to local and non-local forcing.

Statistical relationships of water temperature and atmospheric circulation indices derived from mechanism studies for different regions in the Yellow Sea

Chengyi Yuan[1], Hao Wei, Youyu Lu, Xiaofan Luo and Zhihua Zhang

[1] Tianjin University of Science and Technology

Abstract

Both in-situ and satellite observations of temperature showed significant inter-annual variations and long-term trend in the Yellow Sea (YS), which are important to the modification of ecosystems referred to ocean primary production and fishery. The seeking of statistical relationships between the water temperature and large-scale atmospheric conditions were motivated by the prediction of water temperature. Statistical relationships have been built on the cause and effect relationships derived from mechanism studies based on hindcast simulator for 1958-2007 using a two-way nested global - Northwest Pacific model.

In winter, temperatures in coastal regions of the YS are primarily controlled by variations in latent and sensible heat fluxes at surface due to the East Asian Winter Monsoon, which can be further related to variations of large-scale Arctic Oscillation (AO) index in the Northern Hemisphere. The statistical model of water temperature base on AO index has been established and proved to able to capture the main inter-annual variations. In the Yellow Sea Trough, inter-annual variations of temperature are distinctly different from the surrounding shallow regions, since the influence of lateral heat transport by the Yellow Sea Warm current (YSWC) is significant. Wind stress and deviation of the pathway of the YSWC are both responsible for inter-annual variations of winter

mean temperature, which are suggested by applying Empirical Orthogonal Function analysis and correlation analysis to winter mean temperature, northward velocity of YSWC and curl of wind stress in the central YS. The statistical model for winter temperature in the YSWC region has been built on AO index and leading Principle Component of curl of wind stress, which represented the strength of wind stress and the lateral heat transport influenced by the west/east-ward deviation of the pathway of YSWC to its mean location, respectively.

And in recent studies, wintertime AO can be forecasted for the lead times exceeding 2 months with the state-of-the-art dynamical ensemble prediction systems. Hence, statistical relationships based on atmospheric circulation indices are potentially useful to the temperature prediction in the YS.

Seasonal distribution of dissolved iron in surface water of Sanggou Bay, a typical aquaculture area in China

Xunchi Zhu[1], Ruifeng Zhang[1] and Jing Zhang[1]

[1] State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, PR China

Abstract

Sanggou Bay is one of the largest aquaculture bases in China. In this study, seasonal distribution of dissolved iron (dFe) in the surface water of Sanggou Bay as well as its surrounding rivers and groundwater were investigated during four seasons from April 2013 to January 2014. The average of dFe concentration in surface water of Sanggou Bay in four seasons were 12.01±6.29, 4.72±3.04, 1.83±0.42 and 3.36±2.06 nM, respectively. Different sources contributed dFe into Sanggou Bay following the descending order of atmospheric deposition, rivers and groundwater input. Utilization by the cultivated species of seaweed, scallop and Oyster was the main sink of dFe in Sanggou Bay, which account for over 90% of the dFe removal. The calculation results of Fe* suggested that dFe was sufficient to support the biological utilization of nutrients (DIP) in spring and summer, while iron might be a potential limiting factor for primary production in autumn. High positive correlation between dFe and chlorophyll-a in summer verified the effect of iron on promoting chlorophyll synthesis.

Appendix V: Other Sponsors (Besides the APN)

Sponsorship was provided, as in-kind support, provision of the venue or consumables, or for travel support for lecturers and participants from the following:

Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project

IMBER is an international project that aims to investigate the sensitivity of marine biogeochemical cycles and ecosystems to global change, on time scales ranging from years to decades. IMBER aims to provide a comprehensive understanding of, and accurate predictive capacity for ocean responses to accelerating global change and the consequent effects on the Earth System and human society. IMBER is co-sponsored by the International Geosphere-Biosphere Programme (IGBP), the Scientific Committee on Oceanic Research (SCOR).

Variability and predictability of the ocean-atmosphere system (CLIVAR) project

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

East China Normal University

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

Institute of Marine Research (IMR), Norway

HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH

IMR is Norway's largest centre of marine science. Its main task is to provide advice to Norwegian authorities on aquaculture and the ecosystems of the Barents Sea, the Norwegian Sea, the North Sea and the Norwegian coastal zone. The aim of research and management advice provided by IMR is to ensure that Norway's marine resources are harvested in a sustainable way.

Korean Institute of Ocean Science and Technology

KIOST

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

North Pacific Marine Science Organization (PICES)

PICES

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

Ocean Carbon & Biogeochemistry (OCB)

OCB
Ocean Carbon
& Biogeochemistry

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

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

Past Global Changes (PAGES) project

The Past Global Changes project (PAGES) is an international effort to coordinate and promote past global change research. Its mission is to improve our understanding of past changes in the Earth System in a quantitative and process-oriented way in order to improve projections of future climate and environment, and inform strategies for sustainability.

PAGES brings together more than 6000 scientists from over 100 countries with an interest in the physical climate system, biogeochemical cycles, ecosystem processes, biodiversity, and human dimensions, on different time scales that reach back centuries to hundred thousands of years.

It is a core project of the International Geosphere-Biosphere Programme (IGBP) and Future Earth and is funded by the US and Swiss National Science Foundations and the National Oceanic and Atmospheric Administration (NOAA).

To subscribe to PAGES and receive the PAGES Magazine see: www.pages-igbp.org/my-pages/introduction

Scientific Committee on Oceanic Research

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

State Key Laboratory of Estuarine and Coastal Research (SKLEC), China

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

Appendix VI: Practical Sessions and Group Projects

During the practical sessions and group work in afternoons, participants used several techniques and methods (covered in the lectures) and also discussed and analysed a data set comprising a socio-ecological system.

Some datasets comprised only bio-physical data, others only social or economic data. The groups were required seek other relevant data on the internet. For example, if the dataset contains time series for pelagic fish catch data for Australia, the student group will need to find social and economic data online that will allow them to undertake a relevant socio-ecological analysis. Useful websites are listed in the references.

A: Group Project Instructions

The following suggests a sequence of steps that students may wish to follow to help with the group work.

1. Describe the data set (similar to a meta data description)

(e.g. catches for three pelagic fish species in Eastern Africa from 1990 to 2009, perceptions of the most important effects of marine climate change in three villages in the Solomon Islands in 2012, sea surface temperature measurements for the North Sea from 1960 to 2012).

2. Characterise the main components of the system.

(e.g. the economic data contains increase in GDP and household income, the social data has changes in employment and environmental attitudes, the biological data has changing size of fish, the physical data has changes in Sea Surface temperature)

3. Describe potential links and relationships between the human and bio-physical system (the social-ecological system) even if some of the data/variables are unknown or missing (as this may be data the students can search for – or identify as data gaps)

(e.g. describe how (and why) humans impact the bio-physical system and vice versa)

4. Develop a conceptual model of the links between the different components of the social-ecological system (the bio-physical and human system)

5. Discuss the conceptual model to diagnose interactions

6. Have a detailed look at the data and agree on the question or hypothesis you will work on for the socio-ecological marine system.

(e.g. how will the changes in commercial catch species affect the local economy, what are the likely flow-on effects of predicted sea level rise, how does the resilience in the human system protect the biological integrity of the whole system)

7. Download additional social – economic – catch – or other data you may need from online sources (see the list provided)

8. Carry out computations (e.g. indicators) and statistical analyses of the selected data and/or indicators.

If adequate information exists the system can be modelled using the data and/or indicators

9. Evaluate the results of the analyses and outline the state of the system

10. Identify gaps regarding data and indicators and assess how to address these

11. Highlight trade-offs that had to be made with the analyses, and how to deal with these

12. Suggest several entry points for management of the system

13. Present the results in a way that is useful for management

e.g. Use your conceptual model to explain and diagnose interactions). It might help to think about the links between different objectives (what the aims are for the socio-ecological system), the management actions (what you can do to achieve the aims), the tradeoffs between the different objectives, the indicators that you need to see if you achieve the aims through the management actions you choose to implement.

14. Keep the presentation short and simple. On Saturday morning each group is given 20 minutes to present their findings, with 10 minutes allowed for questions (It helps to pretend that you are explaining the analysis to someone who has no prior knowledge at all).

B: Assigned Groups for the Group Project

The students were divided into the groups to ensure that different skill sets were represented in each group so that they would be able to consider all aspects of the socio-ecological system they investigated.

Group 1

Name	Research interests
Lubna Alam	Chemical risk assessment and management, climate change adaptations in fisheries
Ana Azevedo	Coupled modelling, seagrass water quality
Yang Feng	Impact of humans on marine BGC and ecosystem dynamics
Lucas Kavanagh	Interaction of biogeochemisry, ecosystem structure and fishing pressure (paleo)
Yuri Oh	Ecosystem modelling and physical oceanography
Ashvin Wickramasooriya	Hydrology and coastal management

Group 2

Name	Background
Ricardo Arruda	Carbon export and uptake on continental shelves, primary production

Massimo Di Stefano	Oceanography, informatics, integrating large datasets
Sanna Durgappa	Effect of climate change on marine biodiversity
Toni Mizerek	Quantitative ecology and evolution
Xiujuan Shan	Fish habitat structure change due to human activities
SM Sharifuzzaman	Climate change adaptation, aquaculture
Nandipha Twatwa-Mhlongo	Fisheries management

Group 3

Name	Background
Andrii Bagaiev	Modelling regional climate change on distribution of hazardous anthropogenic substances
Aya Carino	Communicating science-based info, mariculture detection sites
Anindita Das	Marine microbes and the carbon cycle
Carie Hoover	Effects of global change on polar marine ecosystems, resource management
Jesse Lopez	Biogeochemical and climate modelling
Zhonghua Shen	Methods to assess ecosystem services of the open ocean
Xunchi Zhu	Dissolved iron in sea water

Group 4

Name	Background
Pamela Barrett	Trace element distribution effects on primary production and the carbon cycle
Yongliang Duan	Observations and modelling of ocean circulation in the Southern Ocean
Eva Giacomello	Marine ecology, human impacts and socio-economics of seamounts
Mahmudul Islam	Marine resource sustainability, impact of climate change on small scale fishing communities
Vasiliki Lianou	Impact of climate change on benthic planktonic communities

	(paleo)
Xiaona Wang	Biogeochemistry of dissolved organic matter

Group 5

Name	Background
Yan Chang	Biogeochemistry of marine trace metals
Somy Kuriakose	Fisheries stats and modelling and impacts of climate change
Maria José Juan-Jordá	Quantitative marine ecology and fisheries science towards sustainable fisheries management
Shubham Krishna	Marine biogeochemistry modelling
Tyler Rohr	BGC variability in the Southern Ocean
Katrin Tirok	Dynamics of aquatic foodwebs and the adaptation of communities

Group 6

Name	Background
Hadar Berman	Physical-biological interactions in marine ecosystems
Pierre Failler	Effect of climate change on fisheries and fisher migration patterns, fisheries governance in Africa,
Grinson George	Fisheries oceanography
Tianyu Jiang	Hi res climate modelling and climate extremes
Ginevra Rosati	BGC cycles of nutrients and mercury in coastal ecosystems
Feng Shi	Regional climate variations (paleo)
Jooeun Yoon	Climate change and primary production

Group 7

Name	Background
Xujing Davis	Physical oceanography

Giovanni Galli	Modelling response of Mediterranean coral communities to climate change
Rekha J Nair	climate change and fish biology
Kuo-Wei Lan	Satellite oceanography, effects of climate change on fisheries
Natalia Ospina Alvarez	Biogeochemical processes of rivers and estuaries
Paul Suprenand	Fisheries management through ecosystem modelling, bio-indicators

Group 8

Name	Background
Sasmita Das PhD	Marine organic matter dynamics and environmental assessment and management
Maria Fossheim	Effects of climate change on northern marine ecosystems
Dukki Han	Biogeography of Arctic Ocean using microbial indicators
Rajani Panchang	Environmental Impact Assessment of coasts and marginal marine ecosystems (paleo)
Ravindra Rattan	Impact of climate change on food and livelihood security
Chengyi Yuan	Regional ocean dynamics due to large scale climate variability
Petra Schoon	Effects of climate change on the carbon cycle, ocean acidification impacts on microbes

Appendix VII: Database Resources

Websites with useful datasets for socio-ecological assessments

Eurostat is (http://epp.eurostat.ec.europa.eu/) the statistical office of the European Union situated in Luxembourg. Its task is to provide the European Union with statistics at European level that enable comparisons between countries and regions.

Food and Agriculture Organization of the United Nations Fisheries and Aquaculture Department http://www.fao.org/fishery/statistics/collections/en

World Bank databases http://data.worldbank.org/topic

The Sea Around Us project: Fisheries ecosystems and biodiversity (the PEW Charitable Trusts) http://www.seaaroundus.org/data/

The International Monetary Fund publishes a range of time series data on IMF lending, exchange rates and other economic and financial indicators. http://www.imf.org/external/data.htm

A limited amount of global attitude data can be found at Pew Research http://www.pewglobal.org/category/datasets/

Organization for economic cooperation and development (OECD) has an extensive list of datasets but mostly for Europe although some global data is available http://stats.oecd.org/

Appendix VIII: Participants' Reviews

Comments from ClimEco4 participants suggest that it achieved its goal:

"*I enjoyed the diversity of the group", "…an opportunity to learn knowledge from scientists in another research field". "… very useful and it help me think from other perspectives". "The group work and presentations were amazing", "Great career advice". "Very well organised, very welcoming, great atmosphere". "Definitely the best summer school I participated in*".

"I was most impressed by the interactions across multiple disciplines at this summer school, as well as the quality of the lectures. We also had really interesting debates, as we made up quite a unique group of professionals with a wide range of skill sets. Attending this summer school has been an invaluable opportunity to share my work with other researchers. I particularly enjoyed the discussions around data access, metadata curation, and reproducibility of research, which are all very related to my interest in open access to software and data. It was very interesting to realize how researchers from very different fields are met with very similar problems. The "take home message" for me is that communication between scientists, and multidisciplinary approaches are the key to solving complex problems like climate change."

During the summer school, I learned several key concepts that enhanced my research ideas in the field of climate change. Specifically, the summer school taught me the benefits of working in a group. The experience was more than I could have expected and allowed me the freedom to develop and maintain individual accounts as researcher of the team. I actually felt like a major contributor in the group work sessions. The group work I performed allowed me to apply my university learning in a real-world environment and build skills in climate change and fisheries issue. The experience and the skill of data analysis that I developed during the summer school has helped me with my research since returning to my home institute." Dr. Lubna Alam, Institute for Environment and Development, National University of Malaysia.

"*The summer school provided a comprehensive overview of climate change occurring around the world. The classes on indicators were helpful in understanding them better including, selecting indicators, as well as use of proxy indicators where actual ones are not available. Indicator-based decision-making can give managers structured insight into the likely effects of alternative actions, which is essential in integrated management approaches especially in complex fishery scenarios. The close links between the biophysical components of marine ecosystems and the socio-economics of fisheries was also discussed in detail and this will definitely improve the analysis of my present work. The training is helpful for my ongoing research. I have discussed the knowledge I acquired during the summer school with students and fellow colleagues at my institute and have given two lectures to them already. I sincerely thank the APN fund support which helped me in completing the trip and delegation to Shanghai.*" Grinsom George, Central Marine Fisheries Research Institute, Kochi, India

"The ClimEco4 summer school was a very memorable experience for me. It built my capacity in analyzing marine ecosystems and the different ecological and socioeconomic factors and processes inherent in these systems. We learned from the rich experience of the lecturers on how models can simulate these systems, and be used to aid their management. They taught us about indicators, choosing good indicators, and how to use them. I also learned about how to access global databases,

and use global projections. Other that the knowledge I gained from the lectures, I also learned a lot from my interactions with the lecturers and my co-participants. The summer school served as an effective venue for bringing together like-minded people. My interactions with them inspired me to do good research, because I am now part of a community that does research to influence management and policy. I took all these learnings, and I am applying it in the work I am doing here in the Philippines. I am very thankful to APN for making all these possible." Bayosa Aya B. Carino,, University of the Philippines, Diliman, The Philippines

ClimEco4 was fruitful in terms of useful interactions, exposure to recent innovations, ideas and developments, and formulation of new problems for further investigations. The technical inputs and/or suggestions that I receive during the IMBER programme and discussions with authoritative personalities was great help for my research work. Presenting a poster of research gave me a unique opportunity to interact with co-researchers from different parts of the world. Many thanks to the APN for providing funding to aid my trip to the summer school." Dr. D. Sanna Durgappa, Indian Institute of Science (IISc), Bangalore, India

"Participation in ClimEco4 summer school was rewarding for me in a number of ways. I learned how to make model for marine ecosystem management by using different indictors, how to do interdisciplinary research by combining natural science knowledge with social science for policy implications. The summer school participation also enhanced my capacity to do statistical analysis of database. After I came back from the summer school I am supervising two masters student at my university, who will work on developing indicators for Sundarbans mangrove ecosystem management. It also provided an opportunity to build scientific collaboration and networks with different researchers from different parts of the world. I would like to convey my sincere thanks to APN for providing funding for my participation in the ClimEco4 summer school."

Dr. Mohammad Mahmudul Islam, Department of Coastal and Marine Fisheries, Sylhet Agricultural University, Bangladesh

Appendix IX: Acronyms

ClimECO: Climate and Ecosystems

CLIVAR: Climate and Ocean - Variability, Predictability, and Change

ECNU: East China Normal University

IGBP: International Geosphere-Biosphere Programme

IMBER: Integrated Marine Biogeochemistry and Ecosystem Research

IPO: International Project Office

KIOST: Korea Institute of Ocean Science and Technology

OCB: Ocean Carbon Biogeochemistry

PAGES: Past Global Changes

PICES: North Pacific Marine Science Organization

SCOR: Scientific Committee on Oceanic Research

SKLEC: State Key Laboratory of Estuarine and Coastal Research

TWAS: The World Academy of Sciences