# International Symposium

# Climate Change Effects on Fish and Fisheries:

## Forecasting Impacts, Assessing Ecosystem Responses, and Evaluating Management Strategies

April 25 – 29, 2010
Sendai, Japan

# Table of Contents

Abstracts for oral presentations are sorted first by session and then by presentation time. Abstracts for posters are sorted by session and then by paper ID number. Presenter name is in bold-face type and underlined. Some abstracts in this collection are not edited and are printed in the condition they were received.

# Welcome

We welcome you to the beautiful city of Sendai for the International Symposium on "*Climate Change Effects on Fish and Fisheries: Forecasting Impacts, Assessing Ecosystem Responses, and Evaluating Management Strategies*".

The Symposium is providing an opportunity for scientists and policymakers to discuss the potential impacts of climate change on marine ecosystems and our uses of these ecosystems, and to consider strategies that society can take to be prepared for anticipated impacts on fish and fisheries. Response to this event has exceeded our expectations, with more than 350 abstracts submitted by scientists from over 40 countries. The Symposium is arranged around ten theme sessions, with six workshops preceding the meeting. These sessions and workshops encompass a broad range of topics that will provide a global perspective on climate change and the future of the World's fisheries.

This event is the culmination of the planning and preparation of many individuals and organizations. It was made possible by your participation, by the hard work of the local organizers and professionals at the PICES and ICES Secretariats, and by the generous financial support from our sponsors. Without the funds that these organizations entrusted to us, it would have been impossible to achieve our aim of convening a symposium of global scope. We also extend our sincere thanks to all session and workshop convenors, and members of the ICES/PICES Working Group on *Forecasting Climate Change Impacts on Fish and Shellfish* (WGFCCIFS) for their efforts and valuable advice that resulted in an exciting scientific program.

During this week, you will have the opportunity to immerse yourself in the issues, challenges and science of climate change and its influence on marine ecosystems. We anticipate that history will remember this Symposium and its key results as a turning point in addressing the consequences and implications of climate change on fish and fisheries.

We hope our meeting in Sendai will be productive, intellectually rewarding, and we look forward to hearing your ideas and including them in a Symposium proceedings. Enjoy the Symposium!

Anne B. Hollowed, Manuel Barange, Shin-ichi Ito, Suam Kim and Harald Loeng
*Symposium convenors*

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The Japanese Society of Fisheries Science (JSFS)
The Oceanography Society of Japan (JOS)

# Symposium Timetable

| | | | | | |
|---|---|---|---|---|---|
| **Sunday, April 25** | | | | | |
| 09:00<br>17:30 | **Workshop W1**<br>(*Room 7, 3F*)<br>13:00 **Workshop W6**<br>(*Room 7, 3F*) | **Workshop W2**<br>(*Room 2, 1F*) | **Workshop W3**<br>(*Room 6, 3F*) | **Workshop W4**<br>(*Room 1, 1F*) | **Workshop W5**<br>(*Room 4, 2F*) |
| **Monday, April 26** | | | | | |
| **OPENING SESSION**<br>(*Tachibana Hall, 2F*) | | | | | |
| 08:30 | Welcome address on behalf of Symposium convenors | | | | |
| 08:40 | Welcome address on behalf of the host country | | | | |
| 08:50 | Notes from the Local Organizing Committee | | | | |
| 08:55<br>10:40 | **Day 1 Plenary Session**<br>(*Tachibana Hall, 2F*) | | | | |
| 11:00<br>13:00 | **Theme Session P1-D1**<br>(*Tachibana Hall, 2F*) | | | **Theme Session P2**<br>(*Hagi Hall, 2F*) | |
| 14:30<br>18:30 | **Theme Session P1-D1**<br>(*Tachibana Hall, 2F*) | | | **Theme Session A2**<br>(*Hagi Hall, 2F*) | |
| 19:30<br>21:30 | **Welcome Reception**<br>(*Ballroom of Sendai Excel Hotel Tokyu*) | | | | |
| **Tuesday, April 27** | | | | | |
| 09:00<br>13:20 | **Theme Session B1**<br>(*Tachibana Hall, 2F*) | | | **Theme Session A2**<br>(*Hagi Hall, 2F*) | |
| 14:30<br>18:30 | **Theme Session B1**<br>(*Tachibana Hall, 2F*) | | | **Theme Session A1**<br>(*Hagi Hall, 2F*) | |
| 18:30<br>20:30 | **Poster Session**<br>(*Sakura Hall, 2F*) | | | | |
| **Wednesday, April 28** | | | | | |
| 09:00<br>13:15 | **Theme Session C1**<br>(*Tachibana Hall, 2F*) | | | **Theme Session B2**<br>(*Hagi Hall, 2F*) | |
| 14:30<br>18:30 | **Theme Session C2**<br>(*Tachibana Hall, 2F*) | | | **Theme Session D2**<br>(*Hagi Hall, 2F*) | |
| 18:30<br>20:30 | **Poster Session**<br>(*Sakura Hall, 2F*) | | | | |
| **Thursday, April 29** | | | | | |
| 09:00<br>12:00 | **Day 4 Plenary Session P3**<br>(*Tachibana Hall, 2F*) | | | | |
| **CLOSING SESSION**<br>(*Tachibana Hall, 2F*) | | | | | |
| 12:00 | Outcomes from the Symposium by Dr. Steven Murawski | | | | |
| 12:20 | Comments from the audience | | | | |
| 12:40 | Best Presentations Awards | | | | |
| 12:50<br>13:00 | Closing remarks by Symposium convenors | | | | |

All Sessions and Workshops will be held at the Sendai International Center.

# List of Sessions and Workshops

| | |
|---|---|
| P1-D1 | Forecasting impacts: From climate to fish |
| P2 | Forecasting impacts: From fish to markets |
| P3 | Sustainable strategies in a warming climate |
| A1 | Downscaling variables from global models |
| A2 | Species-specific responses: Changes in growth, reproductive success, mortality, spatial distribution, and adaptation |
| B1 | Assessing ecosystem responses: Impacts on community structure, biodiversity, energy flow and carrying capacity |
| B2 | Comparing responses to climate variability among nearshore, shelf and oceanic regions |
| C1 | Impacts on fisheries and coastal communities |
| C2 | Evaluating human responses, management strategies and economic implications |
| D2 | Contemporary and next generation climate and oceanographic models, technical advances and new approaches |
| GP | General Poster Session |
| W1 | Reducing global and national vulnerability to climate change in the fisheries sectors: Policy perspectives post Copenhagen |
| W2 | Potential impacts of ocean acidification on marine ecosystems and fisheries |
| W3 | Coupled climate-to-fish-to-fishers models for understanding mechanisms underlying low frequency fluctuations in small pelagic fish and projecting its future |
| W4 | Salmon workshop on climate change |
| W5 | Networking across global marine “hotspots” |
| W6 | Examining the linkages between physics and fish: How do zooplankton and krill data sets improve our understanding of the impacts of climate change on fisheries? |

# Notes for Guidance

### Presentations

In order to allow the sessions to run smoothly, and in fairness to other speakers, all presentations are expected to adhere strictly to the time allocated. All authors should designate at least 3 minutes for questions.

Authors can download their presentations straight to the computers where the session/workshop will be held.

***Important:*** Please rename your files: time-name.ppt (*e.g.* 0900-Smith.ppt, 1530-Kim.ppt).

If complications occur due to incompatibilities between PCs and Macs, Macintosh owners may use their own computers to make presentations.

### Posters

Posters will be on display in the Sakura Room from 12:00 on April 27. Two evening poster sessions (with appetizers and drinks) will be held from 18:30-20:30 on April 27 and 28, when poster presenters are expected to be available to answer questions. Posters must be removed at the end of the poster session on the evening of April 28.

### Internet access

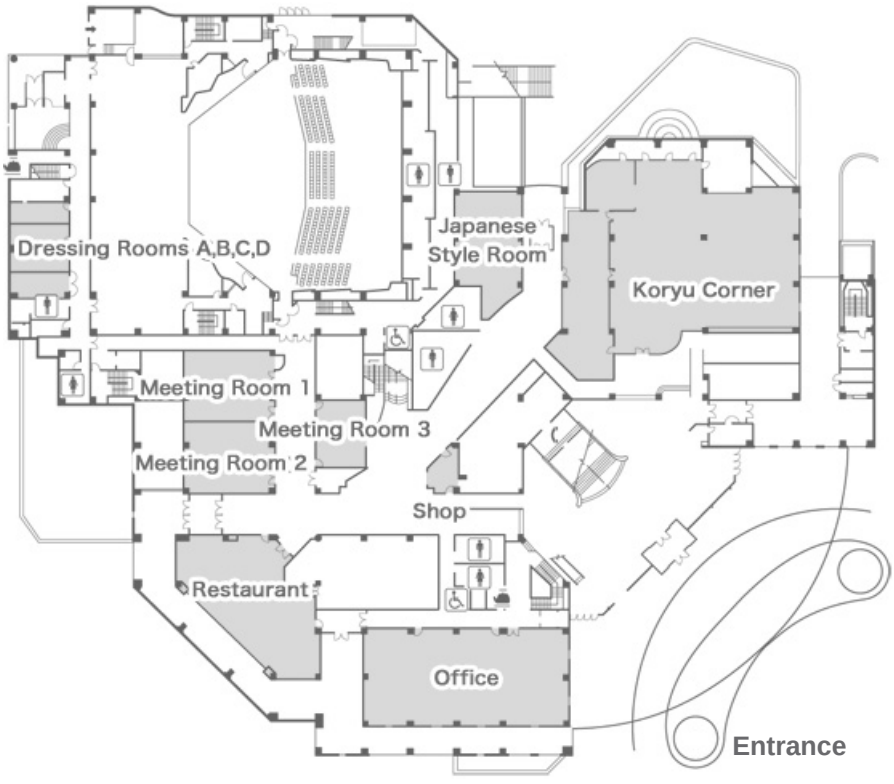
Internet access via wireless LAN will be available at the Sendai International Center. A few desktop computers will also be available for participants.

### Social activities

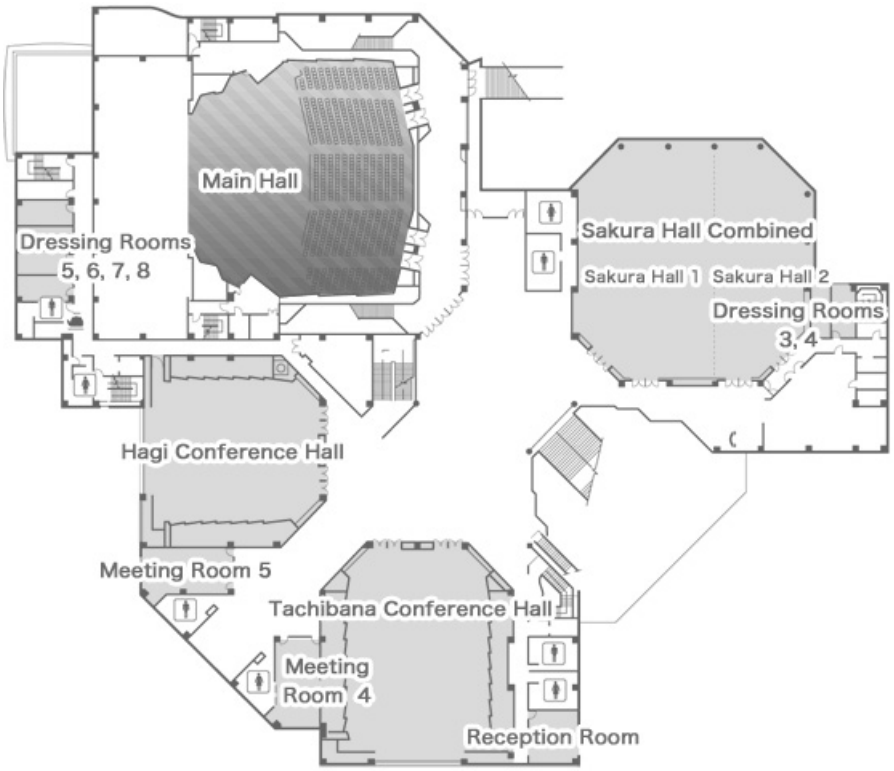
The Welcome Reception for all participants will be held on April 26 from 19:30-21:30 at the Ballroom of Sendai Excel Hotel Tokyu.

# Sendai International Center Floor Plan

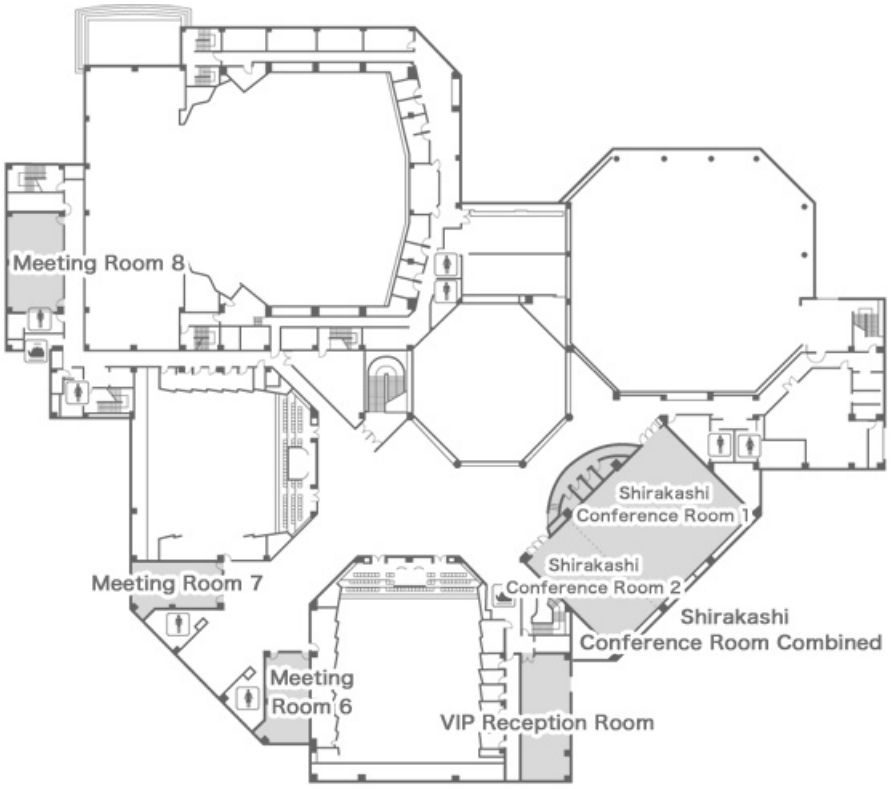
**First Floor (1F)**



**Second Floor (2F)**




**Third Floor (3F)**



# Schedules

# Day 1 Plenary

**Monday, April 26 (8:55-10:40)**

| | |
|---|---|
| 8:55 | **Kevin E. Trenberth**<br>The Earth's climate system: Variability and change (Plenary-6063) |
| 9:25 | **Akihiko Yatsu**<br>Effects of climate change on marine ecosystems around Japan: Implications for sustainable fisheries (Plenary-6127) |
| 9:50 | **Ussif Rashid Sumaila and William L. Cheung**<br>Cost of adapting global marine fisheries to climate change (Plenary-6029) |
| 10:15 | **Edward H. Allison**<br>Climate change in perspective: The global drivers of change in fisheries (Plenary-6413) |
| 10:40 | ***Coffee/Tea Break*** |
| 11:00 | Session ends |

# P1-D1 Forecasting impacts: From climate to fish

***Co-Convenors:***
*Kenneth Drinkwater (Institute of Marine Research, Norway)*
*Harald Loeng (Institute of Marine Research, Norway)*
*Yasuhiro Yamanaka (Hokkaido University, Japan)*
*Franz J. Mueter (School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, USA)*
*Carl O'Brien (Centre for Environment, Fisheries and Aquaculture Science, UK)*

This session will focus on the impacts of future climate change on the physical oceanography, biogeochemistry, and food webs of the world oceans. This includes contributions on appropriate methods for determining impact projections and estimating levels of uncertainty as well as actual development of ecosystem scenarios. Presentations will address downscaling from global models and the problems involved to produce regional future climate and physical oceanographic scenarios, scenarios of climate-induced changes in nutrient dynamics and other biogeochemical processes, changes in ecosystem community structure and function from phytoplankton and zooplankton through to fish populations, including changes in production and distribution and their influence upon biodiversity.

**Monday, April 26 (11:00-18:30)**

| | |
|---|---|
| 11:00 | **James E. Overland, Andrew Bakun, Jürgen Alheit, James Hurrell, David Mackas and Arthur Miller (*presented by Nicholas Bond*)**<br>Match/mismatch of fish population changes to climate events (P1-D1-6045) |
| 11:15 | **Chan Joo Jang and Sinjae Yoo**<br>Change in the North Pacific mixed layer depth and its impact on primary production in a warming world (P1-D1-6315) |
| 11:30 | **William L. Cheung, John P. Dunne, Jorge Sarmiento and Daniel Pauly**<br>Integrating eco-physiology and plankton dynamics into projected global changes in marine biodiversity and maximum catch potential under climate change (P1-D1-6105) |
| 11:45 | **Teruhisa Komatsu, Masahiro Fukuda, Atsuko Mikami, Yutaka Kokubu, Shizuha Mizuno, Hideaki Tanoue and Michio Kawamiya**<br>Possible change in distribution of seaweed, *Sargassum horneri*, in East Asia under A2 scenario of global warming and its impact on fishes (P1-D1-6089) |
| 12:00 | **Stewart Frusher, Gretta Pecl, Caleb Gardner, Marcus Haward, Alistair J. Hobday, Sarah Jennings, Melissa Nursey-Bray, André E. Punt, Hilary Revill and Ingrid van Putten**<br>Fisheries and ecosystems in a changing climate: A case study on the Tasmanian east coast lobster fishery (P1-D1-6313) |
| 12:15 | **George L. Hunt, Jr., Lisa B. Eisner, Edward W. Farley, Jamal H. Moss, Jeffrey M. Napp and Phyllis J. Stabeno**<br>The oscillating control hypothesis: Reassessment in view of new information from the eastern Bering Sea (P1-D1-6036) |
| 12:30<br>(*Cancelled*) | **Martin Huret, Pierre Petitgas and Caroline Struski (*Cancelled*)**<br>The response of fish populations to climate change forecasted by integrating a sequence of models over different life stages: Anchovy in the Bay of Biscay (P1-D1-6364) |
| 12:30 | **Roy Mendelssohn (presented by Frank Shwing)**<br>State-space analysis of ocean and atmospheric data for use in forecasting ecological impacts of climate change (P1-D1-6387) |
| 12:45 | ***Lunch*** |

14:30 **Myron A. Peck, Patricia Reglero, Motomitsu Takahashi and Ignacio A. Catalán**
Life cycle ecophysiology of small pelagic fish: Environmental thresholds and climate-driven changes in populations (P1-D1-6292)

14:45 **Dawit Yemane, Nandipha M. Twatwa and Janet C. Coetzee**
Performance of multiple approaches in modelling small pelagic fish distribution: Predictive ability in the light of climate change (P1-D1-6141)

15:00 **Pierre Fréon, David M. Checkley, Jr. and Francisco E. Werner**
Climate change and small pelagic fish: A review and recommendations (P1-D1-6308)

15:15 **Solfrid Sætre Hjøllo, Geir Huse, Morten D. Skogen and Einar Svendsen**
Modeling secondary production in the Norwegian Sea with a fully coupled physical-primary-secondary production model system (P1-D1-6349)

15:30 **Shin-ichi Ito, Takeshi Okunishi, Michio J. Kishi and Muyin Wang**
Potential impact of climate change on Pacific saury (P1-D1-6266)

15:45 **Kenneth A. Rose, Enrique N. Curchitser, Kate Hedström, Jerome Fiechter, Miguel Bernal, Shin-ichi Ito, Salvador Lluch-Cota, Bernard A. Megrey, Christopher A. Edwards, David M. Checkley, Jr., Alec MacCall, Tony Koslow, Sam McClatchie, Kenneth L. Denman and Francisco E. Werner**
Development of a climate-to-fish-to-fishers model: Proof-of-principle using long-term population dynamics of anchovies and sardines in the California Current (P1-D1-6106)

16:00 ***Coffee/Tea Break***

16:20 **Randall M. Peterman (Invited)**
Uncertainties about climatic change and Pacific salmon: Risk assessment, risk communication, and risk management (P1-D1-6052)

16:45 **Anna Gardmark, Stefan Neuenfeldt, Martin Lindegren, Thorsten Blenckner, Eero Aro, Outi Heikinheimo, Bärbel Müller-Karulis, Susa Niiranen, Maciej Tomczak, Anieke van Leeuwen, Anders Wikström and Christian Möllmann**
Biological ensemble modelling of climate impacts – Improving fisheries science and management by accounting for uncertainty (P1-D1-6301)

17:00 **Franz J. Mueter, Nicholas A. Bond, Anne B. Hollowed, Carol Ladd and Enrique N. Curchitser**
Future recruitment of Bering Sea walleye pollock. Part I: Retrospective patterns and uncertainty (P1-D1-6214)

17:15 **Nicholas A. Bond, Franz J. Mueter, Anne B. Hollowed, Carol Ladd and Muyin Wang**
Future recruitment of Bering Sea walleye pollock. Part II: Ranges in key environmental parameters from global climate model forecasts (P1-D1-6068)

17:30 **Hiroshi Yoshinari, Tomonori Azumaya, Tetsuichiro Funamoto, Akira Kusaka, Orio Yamamura and Akira Nishimura**
Numerical simulations of spatio-temporal distribution of juvenile walleye pollock around Hidaka Bay (P1-D1-6183)

17:45 **Jon Brodziak, Kevin Piner and Dean Courtney**
Modeling recruitment responses of striped marlin (*Tetrapturus audax*) and swordfish (*Xiphias gladius*) to environmental variability in the North Pacific (P1-D1-6396)

18:00 **Kerim Aydin, Nicholas A. Bond, Enrique N. Curchitser, Georgina A. Gibson, Kate Hedström, Albert J. Hermann and Ivonne Ortiz**
Integrating data, fieldwork, and models into an ecosystem-level forecasting synthesis: The modeling challenge of the Bering Ecosystem Study/Bering Sea Integrated Research Program (BEST-BSIERP) (P1-D1-6215)

18:15 **Julia L. Blanchard, Nicholas K. Dulvy, Robert Holmes, Manuel Barange and Simon Jennings**
Potential climate change impacts on fish production from 20 large marine ecosystems around the world (P1-D1-6275)

18:30 Session ends

## Posters

P1-D1-5977 **Nkemasong Samuel Acha and Thomas Tazoche Njang**
The ramification of climate change on aquaculture production in Cameroon

P1-D1-6024 **Hao Wei, Yuheng Wang, Liang Zhao and Michio J. Kishi**
A study of climate impacts on anchovy population dynamics in the Yellow Sea by individual-based model

P1-D1-6074 **Andrei S. Krovnin, Boris Kotenev, Mikhail Bondarenko and Anatoly Morozov (*Cancelled*)**
Factors determining dynamics of highly variable fish stocks and possibilities of its long-range forecasting (taking Northeast Arctic cod as an example)

P1-D1-6075 **Andrei S. Krovnin, Nataliya Klovach and George Moury (*Cancelled*)**
The climatic causes of recent rise of Asian salmon catches and its prospects

P1-D1-6076 **Tatyana V. Belonenko and Aleksey V. Koldunov**
The North-Atlantic Oscillation and biotical cycles within the Azores region

P1-D1-6102 **Camille Albouy, François Le Loc'h, Jean M. Culioli and David Mouillot**
Global warming effects on a Mediterranean ecosystem: A trophic modeling approach on the Bonifacio Straits Natural Reserve (Corsica, France)

P1-D1-6103 **Dmitry K. Staritsyn**
Current divergences and enhanced biological production zones in the Japan Sea according to satellite observations

P1-D1-6114 **M. Aaron MacNeil (*Cancelled*)**
Ignorant academic or a sage fool? Using prior beliefs to forecast climate effects on reef fish communities

P1-D1-6126 **Andrey A. Smirnov, Alexey V. Vakatov and Alexander L. Figurkin**
Changes of increase growth rates and fecundity of the Gizhiga-Kamchatka herring (*Clupea pallasii* Valenciennes, 1847), living in a northeast part of Sea of Okhotsk in connection with fluctuations of a water temperature benthic layer around their wintering grounds

P1-D1-6151 **Alistair J. Hobday, Jason R. Hartog, Richard Matear, Claire M. Spillman and Oscar Alves**
Predicting tuna habitat for spatial fisheries management using electronic tags and ocean models

P1-D1-6176 **Mega Laksmini Syamsuddin, Sei-ichi Saitoh, Samsul Bachri and Agung Budi Harto**
Regional climate change impacts on bigeye tuna (*Thunnus obesus*) catch in the Indonesian Seas

P1-D1-6184 **Ichiro Yasuda, Satoshi Osafune, Shunsuke Konda, Sachihiko Itoh and Hiroyasu Hasumi**
18.6-year period moon-tidal cycle in ocean/climate and its impact on climate/ecosystem predictability

P1-D1-6189 **Chih-Chieh Hsu, Chih-Wei Chang, Chia-Hui Wang, Yuan-Mou Chang, Chen-Feng You and Wann-Nian Tzeng**
The fluctuations of solar activity on catch data of mullet and eel

P1-D1-6195 **Jonathan A. Hare, Mark J. Wuenschel and Matthew E. Kimball**
Larval dispersal, overwinter mortality, and climate change: Forecasting range shifts of a sub-tropical fish species in a western boundary current system

P1-D1-6199 **Joe Scutt Phillips, Graham M. Pilling, Lisa J. Readdy, John K. Pinnegar and Nicholas K. Dulvy**
Do we know the potential impacts of global climate change on fishing nations?

P1-D1-6208 **Trond Kristiansen and Kenneth Drinkwater**
Analyzing warm and cold climate phases to understand differences in survival and connectivity of larval cod: Possible implications for climate change

P1-D1-6221 **Thomas Wilderbuer, Nicholas A. Bond and William Stockhausen**
An example of estimating future Bering Sea northern rock sole productivity from statistical downscaled IPCC models and its effect on management

P1-D1-6263 **Shengyun Yang and Qiulin Zhou**
The impact of climate change on the fishery ecosystems in the Taiwan Strait and their responses

P1-D1-6272 **Arnaud Bertrand, Michael Ballón and Alexis Chaigneau (*Cancelled*)**
Acoustic observation of living organisms reveals the oxygen minimum zone

P1-D1-6283 **Marc Hufnagl, Myron A. Peck, Mark Dickey-Collas, Richard D.M. Nash and Thomas Pohlmann**
Climate-driven, bottom-up control of North Sea herring recruitment

P1-D1-6289 **Yumiko Yara, Masahiko Fujii, Yasuhiro Yamanaka, Naosuke Okada, Hiroya Yamano and Kazuhiro Oshima**
Projected effects of global warming on corals in seas close to Japan

P1-D1-6354 **Miguel Ñiquen, Marilou Bouchon and Milena Arias-Schreiber (*Cancelled*)**
Extreme climatic events and the dynamics of the Peruvian small pelagic fish environment

P1-D1-6380 **Sukyung Kang, Jae Bong Lee, Anne B. Hollowed, Nicholas A. Bond and Suam Kim**
The impact of climate changes on the distribution and abundance of mackerel in the northwestern Pacific

P1-D1-6383 **Franklin B. Schwing, Roy Mendelssohn and Steven J. Bograd**
An assessment of regime shifts in North Pacific ecosystems

P1-D1-6389 **Francisco Beltran, Bruno Sanso, Ricardo Lemos and Roy Mendelssohn**
Indices of temporal variability in North Pacific SST from IPCC model future climate scenarios: A hierarchical Bayesian analysis

# P2 Forecasting impacts: From fish to markets

***Co-Convenors:***
*Manuel Barange (GLOBEC International Project Office)*
*Jacquelynne King (Pacific Biological Station, DFO, Canada)*
*Ian Perry (Pacific Biological Station, DFO, Canada)*

Climate change direct impacts on marine populations will alter the provision of food from our oceans to our markets. At the same time, the on-going process of economic globalization will modify or exacerbate the vulnerability of fish production systems to climate change at global, regional and local level. Policy and management agencies will require scientific advice on the potential impacts that climate change (and its associated economic developments) will have on the availability of fish populations to fisheries, markets and consumers. This session will focus on (1) forecasting changes in marine population dynamics as they relate to fisheries (*e.g.*, impacts on catchability or maximum sustainable yield), to processing and market demands (*e.g.*, changes in size-at-age), to market forces (*e.g.*, changes in price and trade) and to food security (*e.g.*, collective vulnerability analysis); (2) quantifying the uncertainty of these forecasts in risk assessment frameworks useful to resource managers; and (3) exploring the interactivity between the ecosystem and market dynamics.

**Monday, April 26 (11:00-13:00)**

| | |
|---|---|
| 11:00 | **Gorka Merino, Manuel Barange, Christian Mullon, Robert Holmes, Julia L. Blanchard and Lynda Rodwell**<br>Global environmental change scenarios for the world's small pelagic fisheries and global fishmeal and oil markets (P2-6119) |
| 11:15 | **Gakushi Ishimura, Samuel Herrick and Ussif Rashid Sumaila**<br>Can there be stable, cooperative exploitation of a transboundary fish stock under climate variability? A game analysis on the Pacific sardine fishery in the California Current (P2-6290) |
| 11:30 | **Timothy Pickering, Ben Ponia, Cathy Hair, Paul Southgate, Elvira S. Poloczanska, Luc Della Patrona, Antoine Teitelbaum, C.V. Mohan and Michael Phillips**<br>Vulnerability of aquaculture to climate change in the Pacific (P2-6398) |
| 11:45 | **Alan Haynie and Lisa Pfeiffer**<br>Modeling fleet behavior in the Bering Sea pollock fishery under climate change (P2-6359) |
| 12:00 | **Marie-Caroline Badjeck and Tania Mendo Aguilar Wosnitza**<br>Scenarios for the future: Drivers of change in the Peruvian fisheries sector (P2-6367) |
| 12:15 | **Ana Norman-López and Sean Pascoe**<br>The effect of climate change on fishing behaviour in the Eastern Tuna and Billfish Fishery (P2-6071) |
| 12:30 | **Ussif Rashid Sumaila, William L. Cheung and Vicky W.Y. Lam**<br>Impact of climate change on marine resources food security and local economies in West African countries (P2-6230) |
| 12:45 | **Maria A. Gasalla, R. Pincinato and I. Belkin**<br>Ocean proxies for seafood market variability in the South Brazil Bight (P2-6386) |
| 13:00 | Session ends |

# Day 4 Plenary P3

## Sustainable strategies in a warming climate

***Co-Convenors:***
*Anne B. Hollowed (Alaska Fisheries Science Center, NMFS/NOAA, USA)*
*Michael J. Schirripa (Southeast Fisheries Science Center, NMFS/NOAA, USA)*

Many nations have adopted a goal of building sustainable fisheries. Traditionally, this goal has been pursued through the adoption of precautionary harvest policies that are based on the expected productivity of the stock in a future environmental state. However, these harvest policies seldom explicitly consider how possible future climate change may modify critical aspects of the productivity of the stock. At the single species level, climate change could significantly influence the carrying capacity, the reproductive potential, as well as the spatial distribution of the stock. At the multi-species level, climate change may alter the abundance of competitors and predators of species targeted for fishing. Societal changes in the consumption of fish and policies regarding marine ranching and aquaculture may also change the economic factors governing fisheries. This session is intended to explore the future of fish and fisheries under a changing climate. The focus will be on examples of management strategies that could be applied to sustain fisheries under a changing climate and techniques for assessing and forecasting the performance of harvest policies under changing climate. This session is also open to new and novel modeling techniques designed to take into account an uncertain future and/or non-equilibrium conditions in fish, fishing fleets, management, and the marketing of seafood products. This could range from how future fishing vessels may be outfitted to best adapt to a changing climate to how traditional management benchmarks and concepts (maximum sustainable yield, minimum stock size threshold, *etc.*) could be modified or updated to take climate change into account. Inventive ways to circumvent or adapt to the forecasted impacts of climate change and the uncertainty surrounding it are also of interest.

**Thursday, April 29 (9:00-12:00)**

| | |
|---|---|
| 9:00 | ***Introduction by Convenors*** |
| 9:05 | **Chang Ik Zhang and Jae Bong Lee (Invited)**<br>Impacts of climate changes and a pragmatic ecosystem-based approach for assessing and forecasting harvest policies under changing climate in Korea (P3-6212) |
| 9:30 | **Éva Plagányi, Scarla Weeks, Tim Skewes, Mark Gibbs, Elvira S. Poloczanska Ana Norman-López, Laura Blamey, Muri Soares and William Robinson (Invited)**<br>Assessing the adequacy of current fisheries management under changing climate (P3-6073) |
| 9:55 | **Jennifer L. Nielsen, Gregory T. Ruggerone, Christian E. Zimmerman and Jamal H. Moss**<br>Sustainable strategies in a warming climate: Salmon in the Arctic (P3-5996) |
| 10:10 | **Philippe Cury**<br>Moving from fisheries oceanography towards ecosystem oceanography for building scenarios for marine ecosystems under anthropogenic and natural forcing in the XXI Century (P3-6395) |
| 10:25 | **James N. Ianelli**<br>The challenges of developing fisheries stock assessment approaches, harvest control rules, and management strategies to satisfy and adapt to increasingly complex management objectives in a changing environment (P3-6391) |
| 10:40 | ***Cofee/Tea Break*** |

11:00 **Gretta Pecl, Alistair J. Hobday, Stewart Frusher, Warwick Sauer and participants of Workshop 5**
Networking across global marine 'hotspots' (P3-6335)

11:15 **Anne B. Hollowed, Nicholas Bond,Alan Haynie, James N. Ianelli and Franz J. Mueter**
Scenario based models for predicting stakeholder responses to a changing climate: A case study for the Eastern Bering Sea (P3-6240)

11:30 **Yi-Jay Chang, Chi-Lu Sun, Yong Chen and Su-Zan Yeh**
Incorporating climate changes into population dynamic modelling: an individual-based modelling approach for the pronghorn spiny lobster (*Panulirus penicullatus*) in eastern Taiwan (P3-6316)

11:45 **Masahide Kaeriyama, Hyunju Seo and Michio J. Kishi**
Sustainable fisheries management of Pacific salmon in a warming climate (P3-6136)

12:00 Session ends

## Posters

P3-6376 **Manuel Barange, J. Icarus Allen, Eddie Allison, Marie-Caroline Badjeck, Julia L. Blanchard, Ben Drakeford, Nicholas K. Dulvy, James Harle, Jason Holt, Robert Holmes, Simon Jennings, Gorka Merino, Graham M. Pilling and Lynda Rodwell**
QUEST_Fish: Estimating climate change impacts on global fish production and additional vulnerabilities to human societies

P3-6402 **Du Van Toan, Nguyen Van Tien, Vu Thanh Ca, Nguyen Hoang Anh, Nguyen Hai Anh, Vu Thi Hien and Tran The Anh**
Impact assessment of flooding inudation in the Vietnam coastal zone for marine ecosystems by CC and SLR

P3-6411 **Feng-Chen Chang and Shean-Ya Yeh (*Cancelled*)**
Albacore (*Thunnus alalunga*) distribution versus SST in the Indian Ocean based on 1982-2008 log reports of Taiwaneses longliners

P3-6414 **Michael J. Schirripa, Rebecca J. Allee, Russell H. Beard, Stephanie Oakes, Bonnie J. Ponwith, Rebecca Shuford and Roger J. Zimmerman**
An approach to an Integrated Ecosystem Assessment of the Gulf of Mexico

# A1 Downscaling variables from global models

***Co-Convenors:***
*Michael Foreman (Institute of Ocean Sciences, DFO, Canada)*
*Jason Holt (Proudman Oceanographic Laboratory, UK)*

Analyses and summaries recently presented in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicate that many of the dramatic changes observed in the circulation and physical characteristics of the oceans over the past century will continue in the future. As one of the major limitations of the global climate models that are used to estimate these future projections is their relatively coarse resolution, statistical or dynamical downscaling is often needed to provide sufficient spatial detail in the variables of interest. This session will address the downscaling of global climate model variables relevant to marine ecosystems, with emphasis on (1) downscaling techniques and/or their application to particular regions or variables, and (2) analysis of global climate model projections, or results from higher-resolution regional ocean, or coupled atmosphere-ocean models that are forced by, and take their boundary conditions from, global climate models.

## Tuesday, April 27 (14:30-18:30)

14:30 ***Introduction by Convenors***

14:35 **Muyin Wang, James E. Overland and Nicholas A. Bond (Invited)**
Examples of using global climate models for regional marine ecosystem projection (A1-6050)

15:00 **J. Icarus Allen (Invited)**
Shelf seas ecosystems: Past, present and future states (A1-6062)

15:25 **Masao Kurogi, Hiroyasu Hasumi and Yukio Tanaka**
Kuroshio path variation studied by a nested-grid OGCM (A1-6342)

15:40 **Robert Holmes, James Harle, J. Icarus Allen, Jason Holt and Manuel Barange**
Predicting impacts of climate change on primary production in coastal-ocean regions (A1-6190)

15:55 **Jason Holt, James Harle, Rob Holmes and J. Icarus Allen**
Potential climate change impacts on contrasting shelf sea regions: Atmospheric and oceanic impacts *vs.* tidal and seasonal constraints (A1-6294)

16:10 ***Coffee/Tea Break***

16:30 **Enrique N. Curchitser, William Large, Kate Hedström and Jon Wolf**
Downscaling climate simulations in the North Pacific Ocean using a fully coupled multi-scale model (A1-6107)

16:45 **Hiroshi Kuroda, Takashi Setou, Manabu Shimizu and Kazuhiro Aoki**
Dynamical downscaling from the basin scale to submesoscale with a triply nested ocean model (A1-6293)

17:00 **Talgat R. Kilmatov and Elena V. Dmitrieva**
Climatic structural stability of the Kuroshio Extension jet and catastrophe theory (A1-6038)

17:15 **Albert J. Hermann, Kerim Aydin, Nicholas A. Bond, Wei Cheng, Enrique N. Curchitser, Georgina A. Gibson, Kate Hedström, Ivonne Ortiz, Muyin Wang and Phyllis J. Stabeno**
Simulated modes of biophysical variability on the Bering Sea shelf (A1-6375)

17:30 **Huaming Yu, Thomas Pohlmann, Xianwen Bao and Xueen Chen**
Tidal current effects on the simulation of ocean circulation by theoretical and numerical analyses (A1-6264)

17:45 **Alexandra V. Temnykh, Yuriy N. Tokarev and Viktor V. Melnikov**
The Black Sea zooplankton-climate connection: A multi-scale approach and new methods (A1-6017)

18:00 **Michael Foreman, Badal Pal, William Merryfield, Diane Masson and John Morrison**
Toward a regional climate model for the British Columbia continental shelf (A1-6069)

18:15 **Elena I. Ustinova**
Evaluation of potential limitations for statistical downscaling in the Far-Eastern Seas (A1-6393)

18:30 Session ends

## Poster

A1-6347 **Anne D. Sandvik, Solfrid Sætre Hjøllo and Anne Britt Sandø**
Downscaling global climate predictions for the North Sea - A discussion about quality

# A2 Species-specific responses: Changes in growth, reproductive success, mortality, spatial distribution, and adaptation

***Co-Convenors:***
*Richard Beamish (Pacific Biological Station, DFO, Canada)*
*Myron Peck (Center for Marine and Climate Research, University of Hamburg, Germany)*

Climate is now recognized as a major factor affecting the productivity of key species in world fisheries. The mechanisms that link climate to fish productivity need to be better understood to ensure that natural and greenhouse gas induced climate changes are incorporated into the management of fisheries. Population-level changes in commercially and ecologically important marine fish species may result from climate-driven changes in organismal-level vital rates (*e.g.*, changes in growth, reproductive success and mortality). Furthermore, expansion, contraction and/or shifts in the distribution of fish stocks will result from changes in suitable habitats (habitats that allow connectivity among life stages, life cycle closure and successful recruitment). The extent of climate-driven changes will be mediated by the capacity for individual species (or populations) to adapt to changes in important abiotic and biotic factors. Adaptations could include both changes in the phenology of important life history events (*e.g.*, migration, spawning) and/or physiological changes (*e.g.*, thermal reaction norms of key traits such as growth, increased tolerance to lowered pH/ocean acidification). This session provides a forum for presentations focusing on the response of key fish and fisheries species worldwide to climate change by: (1) documenting historical, long-term fluctuations in abundance and distribution, (2) discussing processes underlying current changes, and/or (3) projecting future impacts in light of adaptive capacity. Key fisheries species include those utilizing marine habitats during any portion of their life cycle and that are commercially or ecologically important marine resources.

## Day 1, Monday, April 26 (14:30-18:30)

14:30 ***Introduction by Convenors***

14:35 **Hans-O. Pörtner (Invited)**
Oxygen- and capacity-limitation of thermal tolerance: A matrix for integrating climate-related stressor effects in marine ecosystems (A2-6085)

15:00 **Olav Sigurd Kjesbu, Jon Egil Skjæraasen, David Righton, Kathrine Michalsen, Christian Jørgensen, Anders Frugård Opdal and Peter R. Witthames**
Climate effects on maturation and spawning of Atlantic cod and implications for fisheries (A2-6099)

15:15 **So Kawaguchi, Haruko Kurihara, Robert King, Lillian Hale, Thomas Berli, James Robinson, Patti Virtue, Stephen Nicol and Atsushi Ishimatsu**
An experimental assessment of effects of raised $pCO_2$ on early-larval Antarctic krill (A2-6153)

15:30 **Jun Shoji, Masakazu Hori, Yasuhiro Kamimura, Ken-ichiro Mizuno and Shun-ichi Toshito**
Fish production in coastal habitats under global warming: Spatio-temporal variability in early growth of a dominant species, black rockfish, in seagrass beds (A2-6090)

15:45 **Frida Ben Rais Lasram, Francois Guilhaumon, Samuel Somot, Wilfried Thuiller and David Mouillot**
The Mediterranean Sea as a trap for endemic fishes facing climate change (A2-6020)

16:00 ***Coffee/Tea Break***

16:20 **John K. Pinnegar, Georg Engelhard, Julia L. Blanchard, Joe Scutt-Phillips and William L. Cheung (Invited)**
How has climate change impacted marine food-webs in the past, and how might we predict changes in the future? (A2-6362)

16:45 **Louis W. Botsford, Matthew D. Holland, Alan Hastings, Michael J. Fogarty, Francis Juanes and Hui-Yu Wang**
The effects of fish life histories on time scales of response to environmental change (A2-6109)

17:00 **Remment ter Hofstede and Adriaan D. Rijnsdorp**
Disentangling the effects of fisheries and climate change on fish communities (A2-6080)

17:15 **Manuel Hidalgo, Valerio Bartolino, Santiago Cerviño, Angélique Jadaud, Enric Massutí, Fran Saborido-Rey, Marina Santurtún and Nils Christian Stenseth**
Comparative study of fishing-induced juvenescence effects under different climatic and fishing harvesting scenarios (A2-6145)

17:30 **J. Marti Pujolar, D. Bevacqua, M. Andrello and L. Zane**
Bringing together molecular genetics and population dynamics modelling: Disentangling the influence of fisheries and climate variation in the endangered European eel (A2-6034)

17:45 **Yongjun Tian, Hideaki Kidokoro, Tatsuro Watanabe, Yosuke Igeta, Hideo Sakaji and Ken Watanabe**
Response of yellowtail *Seriola quinqueradiata* in the Japan Sea to sea water temperature over the last century and potential effect of global warming (A2-6115)

18:00 **Adriaan D. Rijnsdorp, Ralf van Hal, Marc Hufnagl, Richard D.M. Nash, Alexander Schroeder, Lorna R. Teal, Ingrid Tulp, Rob Witbaard, Doug Beare and Henk W. van der Veer**
Key mechanism determining the impact of climate change on the productivity and fisheries of North Sea plaice, *Pleuronectes platessa* L. (A2-6258)

18:15 **Michele Casini, Valerio Bartolino, Juan Carlos Molinero and Georgs Kornilovs**
Linking climate, trophic interactions and fisheries: Threshold dynamics drive herring (*Clupea harengus*) growth in the central Baltic Sea (A2-6345)

18:30 Session ends

## Day 2, Tuesday, April 27 (9:00-13:20)

9:00 **Kuo-Wei Lan, Ming-An Lee and Hsueh-Jung Lu**
A study on yellowfin tuna (*Thunnus albacares*) stocks and fishing conditions in relation to oceanic environmental variation in the Atlantic Ocean (A2-6171)

9:15 **Nan-Jay Su, Chi-Lu Sun, André E. Punt and Su-Zan Yeh**
Impacts of climate change on the distribution of blue marlin (*Makaira nigricans*) as inferred from data for longline fisheries in the Pacific Ocean (A2-6295)

9:30 **Barbara Muhling, Sang-Ki Lee, Michael J. Schirripa, Walter Ingram and John Lamkin**
Predicting the effects of climate change on bluefin tuna (*Thunnus thynnus*) spawning habitat in the Gulf of Mexico (A2-6032)

9:45 **Melanie Abecassis, Patrick Lehodey, Inna Senina and Jeffrey J. Polovina**
Swordfish population dynamics in the Pacific Ocean (A2-6110)

10:00 **Yury I. Zuenko, Lydmila A. Chernoivanova, Alexander N. Vdovin and Elena I. Ustinova**
Climate change effect on the saffron cod *Eleginus gracilis* reproduction, stock, and fishery in the Japan Sea (A2-6227)

10:15 **Z. Teresa A'mar, André E. Punt and Grant G. Thompson**
Incorporating climate variability into the assessment of Gulf of Alaska Pacific cod (A2-6239)

10:30 **Rüdiger Voss, Hans-Harald Hinrichsen, Jörn O. Schmidt and Martin F. Quaas**
Spatially resolved impact of temperature change on recruitment of sprat and cod in the Baltic Sea – From observation to bio-economic modeling (A2-6202)

10:45 ***Coffee/Tea Break***

11:05 **Harald Loeng, Hjámar Hátún, Jens Christian Holst, Mark Payne and Aril Slotte**
The rise and the fall of the northern blue whiting stock (A2-6191)

11:20 **Eduardo Martins, Scott Hinch, David Patterson, Merran Hague, Steven Cooke, Kristina Miller, Michael Lapointe, Karl English and Anthony Farrell**
Effects of river temperature and climate warming on stock-specific survival of adult migrating Fraser River sockeye salmon (*Oncorhynchus nerka*) (A2-6028)

11:35 **Hyunju Seo, Masa-aki Fukuwaka and Masahide Kaeriyama**
Long-term fluctuations in somatic growth, survival, and population dynamics of Hokkaido chum salmon, *Oncorhynchus keta*, linking to climate changes (A2-6179)

11:50 **Juan L. Valero, Steven R. Hare and Bruce M. Leaman**
Investigating the roles of climate, density-dependence and fishing on long-term and large-scale changes in recruitment, growth, maturity and distribution of Pacific halibut (A2-6173)

12:05 **Yasunori Sakurai, A.L. Rosa and J. Yamamoto**
Past, present and future of Japanese common squid, *Todarodes pacificus* (Cephalopoda: Ommastrephidae) (A2-6156)

12:20 **Jacob F. Schweigert, Jennifer Boldt, Linnea Flostrand, Peter Olesiuk, Sherri Dressel and Ryan Watanabe**
Differing response of herring stocks to ecosystem forcing in the California and Gulf of Alaska Current systems (A2-6250)

12:35 **Akinori Takasuka, Sam McClatchie, Ed Weber, Yoshioki Oozeki, Takahiko Kameda, Yuichi Hirota and Hiroshi Okamura**
Responses of anchovy and sardine spawning to physical and biological factors in the Kuroshio and California Current systems: Interspecific and intersystem comparison (A2-6338)

12:50 **Janet A. Nye, Jason S. Link and Jonathan A. Hare**
Climate-induced changes in distribution of Northwest Atlantic fish and invertebrates: Implications for management (A2-6196)

13:05 **Benjamin Planque, Edwige Bellier, Frida Ben Rais Lasram and Christophe Loots**
Now you see me, now you don't: Uncertainties in projecting future spatial distribution of marine populations (A2-6019)

13:20 Session ends

## Posters

A2-6022 **Alexander M. Kaev (presented by A. Velikanov)**
Possible inner causes for correcting "climatic" trends in pink salmon

A2-6030 **Claudio Castillo-Jordán, Luis A. Cubillos and Eduardo Navarro**
Inter-cohort growth rate changes of common sardine (*Strangomera bentincki*) and their relationship with environmental conditions off central southern Chile

A2-6033 **Melissa A. Haltuch, Carrie Holt, André E. Punt and M. Elizabeth Clarke**
Patterns and processes underlying Pacific hake (*Merluccius productus*) migrations: Progress on developing forecast tools to predict distribution and density

A2-6041 **Mei-Yu Chang and Audrey J. Geffen**
Classifying the spatial structure of different spawning populations of commercially important Atlantic and Mediterranean Sea by otolith elemental composition

A2-6058 **Valerio Bartolino, Piotr Margonski, Massimiliano Cardinale, Martin Lindegren, Hans Linderholm, Hakan Wennhage and Michele Casini**
Herring recruitment in the Baltic Sea: From observations to projections

A2-6059 **Guimei Liu, Song Sun and Hui Wang (*Cancelled*)**
Modelling the demography of *Calanus sinicus* in the Yellow Sea Cold Water Mass

A2-6060 **Elizabeth Atwood, John K. Horne, Janet T. Duffy-Anderson and Carol Ladd**
Association of larval fish abundance with mesoscale eddies in the Gulf of Alaska

A2-6070 **Nandipha M. Twatwa, Dawit Yemane and Janet C. Coetzee**
Pattern of habitat preference by three small pelagic species in the southern Benguela during high and low biomass periods

A2-6077 **Alexander Arkhipkin and Vladimir Laptikhovsky**
Environmental changes caused recent increase in abundance of rock cod, *Patagonotothen ramsayi* in the Southwest Atlantic

A2-6082 **Matthew T. Wilson, Kathy Mier and Annette Dougherty**
The first annulus of otoliths: A tool for studying intra-annual growth among walleye pollock (*Theragra chalcogramma*)

A2-6083 **Kathryn Hughes, Mark P. Johnson and Leonie Dransfeld**
Warming seas and the migration of Atlantic mackerel

A2-6092 **Jennifer M. Donelson, Philip L. Munday and Mark I. McCormick**
Thermal acclimation by a coral reef fish

A2-6094 **Yasuo Itoh, Yukihiko Watanabe, Yukio Nakamura, Shuji Tsuchida, Hideaki Kinoshita, Takumi Setoguma and Yasushi Minowa**
Comparison of swimming performance at various acclimation temperatures for teleosts inhabiting Japanese coastal waters

A2-6097 **Shan Gao, Hui Wang and Liu Guimei**
Spatial and temporal variability of chlorophyll *a* and their responses to marine environments in the South China Sea

A2-6111 **Claudio Gatica, Claudio Castillo-Jordán, Sebastian Vasquez and Rubén Alarcón**
Population structure changes on size and age composition on Chilean hake (*Merluccius gayi gayi*) and their association with environmental conditions

A2-6112 **Strahan Tucker, Marc Trudel, David W. Welch, John R. Candy, John F.T. Morris, Mary E. Thiess, Colin Wallace and Terry D. Beacham**
Annual trends in seasonal stock- and life-history-specific ocean migration of juvenile Chinook salmon *Oncorhynchus tshawytscha*: An application of genetic identification techniques

A2-6120 **Masao Miura, Toshiro Fujisawa, Hiroshi Yamada and Takeya Hara**
Behavioral response of Japanese amberjack, *Seriola quinqueradiata*, to sea water temperature rise caused by thermal effluent

A2-6139 **Svetlana A. Murzina, Stig Falk-Petersen, Jørgen Berge and Nina N. Nemova**
Seasonal lipid and fatty acids dynamics in *Leptoclinus maculatus* larvae from Svalbard waters in relation to abiotic and biotic factors

A2-6142 **N.M. Twatwa, Dawit Yemane and Janet C. Coetzee**
Modeling the distribution and abundance of pelagic fish species as a function of environmental variables

A2-6160 **Haruka Nishikawa, Ichiro Yasuda, Sachihiko Itoh, Hideharu Sasaki and Yoshikazu Sasai**
Environmental impacts on long-term variation in recruitment success of Japanese sardine

A2-6161 **Rubén Rodríguez-Sánchez, Carl van der Lingen, Marlene Manzano, Larry Hutchings and Héctor Villalobos**
Comparing the influence of oceanographic fronts on interannual changes in the distribution and relative abundance of sardine in the California and Southern Benguela Current systems

A2-6187 **Jung Jin Kim and Suam Kim**
Relationship between environmental variability and distribution of common squid (*Todarodes pacificus*) paralarvae in the northern East China Sea

A2-6200 **Ana Moreira, Paulo Fonseca, Cristina Silva, Aida Campos, Maria de Fátima Borges and Miguel Santos**
Are crustacean landings from Portuguese waters driven by environment variables?

A2-6217 **Omar I. Abdul-Aziz and Nathan J. Mantua**
Climate change impacts on the ocean distributions of Pacific salmon

A2-6224 **Bernard A. Megrey, Kenneth A. Rose, Jacob F. Schweigert, Douglas Hay, Francisco E. Werner, Yasuhiro Yamanaka and Shin-ichi Ito**
Geographic variation in Pacific herring growth and population responses to regime shifts in the North Pacific basin

A2-6246 **Christos D. Maravelias and Alex Tidd**
Northern *vs.* southern European Seas: Investigating spatio-temporal patterns of *Mullus surmuletus* distribution in relation to environmental changes

A2-6251 **Sukgeun Jung**
Recruitment and migration of Pacific cod (*Gadus macrocephalus*) to southern Korean coastal waters in relation to variations in the bottom cold waters originating from the Japan/East Sea

A2-6254 **Motomitsu Takahashi, Yoshiro Watanabe, Akihiko Yatsu and Hiroshi Nishida**
Contrasting responses in larval and juvenile growth rates of anchovy and sardine to a climate-ocean regime shift: Implications for their population dynamics

A2-6255 **Akiko Takano, Hidekatsu Yamazaki, Osamu Honda, Kotaro Yokawa and Hiroshi Shono**
An investigation of the relationship between bigeye tuna (*Thunnus obesus*) catch and three dimensional thermal structures

A2-6260 **Cheryl A. Morgan, William T. Peterson, Joseph P. Fisher and Jesse F. Lamb**
Effects of climate variability on the distribution, abundance and habitat usage of juvenile salmonids in the coastal waters of the northern California Current

A2-6270 **Yuu Katsukawa, Yoshiro Watanabe, Hiroshi Okamura, Tatsuya Suzuki and Hisashi Nakategawa**
Changes in the life history traits of Japanese anchovy and sardine

A2-6280 **Jörn O. Schmidt and Rüdiger Voss**
The rise and fall of snake pipefish (*Entelurus aequoreus* L.) off North Scotland

A2-6314 **Caleb Gardner and Stewart Frusher (*Cancelled*)**
Warming influences productivity of lobster stocks in SE Australia

A2-6317 **Andrew Tobin, Audrey Schlaff, Besse Krause, David W. Welch, Tony Ayling, Hugh Sweatman, Paul Marshall, Brigid Kerrigan and Jeff Maynard**
Contrasting ecological responses of two commercially important finfish to severe tropical cyclones: A sullen serranid and a lively lethrinid

A2-6319 **Haruko Kurihara, Yuji Hiratsuka, Takamasa Asai, Atsushi Ishimatsu, Laura Parker and Pauline Ross**
Are geographically distinct populations similarly impacted by ocean acidification? (Oysters as a case study)

A2-6331 **Kinuyo Fukamichi, Yoshiro Watanabe, Isamu Mitani and Tomohiko Kawamura**
Metamorphosis is closely associated with condition factor in Japanese anchovy in the Pacific coast waters of central Japan

A2-6334 **Mika Suhara, Yoshiro Watanabe, Yuu Katsukawa, Yasuo Mori, Satoshi Katayama, Masayuki Yamamoto and Tomohiko Kawamura**
Comparative reproductive ecology of Japanese anchovy, *Engraulis japonicus*, in different current areas off Japan

A2-6343 **Chen-Te Tseng, Chi-Lu Sun, Su-Zan Yeh, Shih-Chin Chen and Wei-Cheng Su**
Influence of environmental factors on the distributions of Pacific saury in the northwestern Pacific Ocean

A2-6350 **Cecilie Kvamme, Geir Odd Johansen, Jan Erik Stiansen, Trond Westgard, Bjørn Adlandsvik and Sigrid Lind Johansen**
Ocean temperature, cod stock distribution and cod fisheries in the Barents Sea the last decades

A2-6377 **Stephani Zador and Kerim Aydin**
Patterns in a changing climate: Fine-scale analysis of arrowtooth flounder catch rates in the eastern Bering Sea reveals spatial trends in abundance and diet

# B1 Assessing ecosystem responses: Impacts on community structure, biodiversity, energy flow and carrying capacity

***Co-Convenors:***
*Thomas Okey (Pew Fellow / UVic / Bamfield Marine Station, Canada)*
*Akihiko Yatsu (Seikai National Fisheries Research Institute, FRA, Japan)*

Assessing effects of climate change on marine ecosystems (*i.e.*, biological communities) is a major challenge, mainly because (1) future changes in physical forcing, such as water temperature, will exceed historically observed values, and (2) biological responses or adaptations to these changes are highly uncertain, particularly over a long time period. Changes in geographic ranges, vertical distributions, phenologies, population structures, and productivities will differ among individual species thereby altering the connectivities and functions of ecosystem components, including predator-prey relationships and competition, species assembly, community structure, biodiversity, energy flow, and carrying capacity. This session will focus on retrospective analyses of changes in freshwater, coastal, and offshore ecosystems/communities, experimental studies on species interactions under climate-change-related conditions, and conceptual and numerical modelling of ecosystems relevant to climate change.

**Tuesday, April 27 (9:00-18:30)**

9:00 ***Introduction by Convenors***

9:05 **Jeffrey J. Polovina, John P. Dunne, Phoebe Woodworth and Evan A. Howell (Invited)**
Possible trends in North Pacific ecosystems over the 21st century based on output from a coupled climate, biogeochemical, and phytoplankton model (B1-6053)

9:30 **Hiroshi Sumata, Taketo Hashioka, Takeshi Okunishi, Masahito Shigemitsu, Maki N. Aita, Naoki Yoshie, Naosuke Okada, Takashi T. Sakamoto, Tatsuo Suzuki and Yasuhiro Yamanaka**
Effects of climate forcing on the North Pacific Ocean ecosystem simulated using an eddy-permitting marine ecosystem model (B1-6167)

9:45 **Jeffrey M. Napp, George L. Hunt, Jr., Lisa B. Eisner, Edward W. Farley, Phyllis J. Stabeno, Alex Andrews and Atsushi Yamaguchi**
The response of eastern Bering Sea zooplankton communities to climate fluctuations: Community structure, biodiversity, and energy flow to higher trophic levels (B1-6049)

10:00 **Hung-Yen Hsieh, Wen-Tseng Lo, Long-Jing Wu, Huang-Pin Chien, Deng-Cheng Liu and Wei-Cheng Su**
Larval fish assemblages in the waters around Taiwan, western North Pacific: A comparison between, during and after the northeasterly monsoon (B1-6168)

10:15 **Nadezhda L. Aseeva and Alexander L. Figurkin**
Changes of bottom ichthyocenosis structure on the shelf of west Kamchatka under changing environments in the last two decades (B1-6235)

10:30 **Rebecca G. Asch and David M. Checkley, Jr.**
Climate change leads to earlier seasonal occurrence of larval fishes in the southern California Current (B1-6216)

10:45 ***Coffee/Tea Break***

11:05 **William J. Sydeman, Bryan A. Black, Steven J. Bograd, Jeff Dorman, John C. Field, Kyra L. Mills, Stephen Ralston, T. Zack Powell, Jarrod A. Santora, Isaac D. Schroeder, Sarah Ann Thompson and Franklin B. Schwing**
Ocean climate change and phenology: Effects on trophic synchrony and consequences to fish and seabirds in the northern-central California Current (B1-6220)

11:20 **Takafumi Hirata, Robert Brewin and Nick Hardman-Mountford**
Global distribution of phytoplankton functional types estimated from satellite ocean colour (B1-6042)

11:35 (*Cancelled*) **Jacquelynne R. King, Vera N. Agostini, Gordon McFarlane, Christopher Harvey, Michael Foreman, James E. Overland and Kerim Aydin (*Cancelled*)**
Climate Forcing and Marine Ecosystems of the North Pacific (B1-6108)

11:50 **Gregory N. Nishihara and Ryuta Terada**
A preliminary study of the effects of a wave exposure gradient on the species richness of marine macrophytes along the eastern rim of the East China Sea (B1-6279)

12:05 **Sukgeun Jung, Young Shil Kang, Young-Sang Suh, Sukyung Kang and Yeong Gong**
Climate-driven shifts in marine fish communities indicated by commercial catch statistics from Korean coastal waters (B1-6253)

12:20 **Hiroya Sugisaki, Kiyotaka Hidaka, Tadafumi Ichikawa, Yutaka Hiroe, Yuichi Hirota, Kenji Morinaga, Manabu Shimizu, Takahisa Tokunaga, Mikiko Kuriyama, Tomowo Watanabe and Kaoru Nakata**
Interdisciplinary monitoring for the Kuroshio warm current ecosystem in relation to climate change (B1-6329)

12:35 **Hiroaki Saito, Shin-ichi Ito, Atsushi Kawabata, Mitsutaku Makino, Masami Nonaka, Takeshi Okunishi, Kazutaka Takahashi and Ichiro Yasuda**
Understanding and forecasting of fish species alternation in the Kuroshio-Oyashio ecosystem: The SUPRFISH programme (B1-6101)

12:50 ***Lunch***

14:30 **Elizabeth A. Fulton (Invited)**
Interesting times (B1-6044)

14:55 **Rosamma Stephen**
Decline in mackerel fishery along west coast of India and its relation to the diminishing density of an abundant upwelling copepod: A multi-decadal study (B1-6164)

15:10 **Sunil D. Ahirrao**
Effect of climate change on fish and fisheries of Marathwada region of Maharashtra state (India) (B1-6336)

15:25 **Stephen D. Simpson, Mark P. Johnson, David W. Sims, Pieter-Jan Schön, Julia L. Blanchard, Simon Jennings and Martin J. Genner**
Long-term climate-driven changes in UK marine fish communities (B1-6056)

15:40 **Remment ter Hofstede, Jan Geert Hiddink and Adriaan D. Rijnsdorp**
Global warming changes the species richness of marine fish in the eastern North Atlantic Ocean (B1-6078)

15:55 **Gabriel Reygondeau, Olivier Maury, Hervé Demarcq and Philippe Cury**
Changes in the environmental factors controlling the global biogeography of tuna and billfish communities (B1-6305)

16:10 ***Coffee/Tea Break***

16:30 **Charles A. Stock and John P. Dunne**
Modeling global patterns in the transfer of energy between primary producers and mesozooplankton in a global circulation model (B1-6366)

16:45 **Ryan R. Rykaczewski and John P. Dunne**
Comparison of the ecosystem response to climate change in the mid-latitude North Pacific and California Current ecosystems (B1-6363)

17:00 **Evan A. Howell, John P. Dunne and Jeffrey J. Polovina**
Modeling the central North Pacific ecosystem response to predicted climate variations and fishery management scenarios (B1-6061)

17:15 **William L. Cheung, Thomas A. Okey and Richard D. Brodeur**
Projecting future change in pelagic nekton communities along the west coast of North America (B1-6276)

17:30 **Matthew T. Wilson, Christina M. Jump and Andre Buchheister**
Ecology of small neritic fishes in the western Gulf of Alaska: Top-down mechanisms can moderate bottom-up forcing (B1-6081)

17:45 **Philip L. Munday, Danielle L. Dixson, Mark I. McCormick and Mark Meekan**
Ocean acidification threatens the replenishment of reef fish populations (B1-6130)

18:00 **Nicholas Graham, Pascale Chabanet, Richard Evans, Simon Jennings, Yves Letourneur, M. Aaron MacNeil, Tim McClanahan, Marcus Öhman, Nicholas Polunin and Charles Sheppard**
Extinction vulnerability of coral reef fishes in response to climate change and fisheries exploitation (B1-6095)

18:15 **Nam-Il Won, Tomohiko Kawamura, Hideki Takami, Hiroshi Hoshikawa and Yoshiro Watanabe**
Comparison of benthic community structure in natural habitats of abalone *Haliotis discus hannai* affected by different current systems (B1-6328)

18:30 Session ends

## Posters

B1-6025 **Skip McKinnell and Enrique N. Curchitser**
Thermal refugia in the 21st century

B1-6046 **C. Tracy Shaw, Leah R. Feinberg and William T. Peterson**
Potential effects of climate change on the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* off Newport, OR, USA

B1-6067 **Toby D. Auth, Richard D. Brodeur, Heather L. Soulen, Lorenzo Ciannelli and William T. Peterson**
Long-term changes in fish larvae in the northern California Current in relation to climate variability

B1-6091 **Genta Takeda, Yoshinari Endo and Waka Sato-Okoshi**
Seasonal change in species composition of hydromedusae and the effect of environmental change in Onagawa Bay, northeastern Japan

B1-6100 **Kate E. Watermeyer, A. Jarre, L.J. Shannon and Larry Hutchings**
Ecosystem implications of the recent southward shift of key components in the southern Benguela

B1-6125 **Wen-Tseng Lo, Hung-Yen Hsieh, Dong-Chung Liu and Wei-Cheng Su**
Effect of water masses on larval fish distribution during the summer SW monsoon in Taiwanese waters, western North Pacific

B1-6170 **Tsuneo Ono, Kazuaki Tadokoro and the A-line Monitoring Team**
Ecosystem responses to ocean stratification and early-bloom occurrence in the future western subarctic North Pacific: A speculation from retrospective analyses

B1-6175 **Sachihiko Itoh, Ichiro Yasuda, Tohru Ikeya and Haruka Nishikawa**
Time series observations of chlorophyll fluorescence along the Kuroshio Extension by profiling floats

B1-6223 **Andrey Suntsov and Tony Koslow**
Long-term temporal trends in ichthyoplankton community composition in the southern California Current System

B1-6238 **Rubén J. Lara, Germán A. Kopprio, Carlos A. Strüssmann and Hugo Freije**
Uncertain future of fish populations in Argentinean coastal lakes: The impact of severe droughts and floods

B1-6274 **Sekharapilla Premjith**
Studies on the hydrobiology of the coconut husk retting grounds in the AVM Canal in Thoothoor region, southwest coast of India

B1-6333 **Yuji Okazaki and Kazuaki Tadokoro**
Early life history of *Euphausia pacifica* in the western North Pacific

B1-6382 **Juan Carlos Molinero, Michele Casini, Jakov Dulcic, Branka Grbec, Manuel Hidalgo, Lyudmila Kambourska, Andreas Lehman, Marcos Llope and Mira Morovic**
Climate and fishing pressure drive a non stationary behaviour in the long-term changes of pelagic food webs in European Shelf Seas

B1-6415 **Yu-Kai Chen, Yi-Jay Chang, Chi-Lu Sun, Chi-Lun Wu, Dong-Chung Liu and Wei-Cheng Su**
Identification of the relationship between environmental features and copepod abundances in the Kuroshio waters adjacent to eastern Taiwan using generalized additive models

B1-6425 **Jacquelynne R. King, Vera N. Agostini, Gordon McFarlane, Christopher Harvey, Michael Foreman, James E. Overland and Kerim Aydin**
Climate Forcing and Marine Ecosystems of the North Pacific

# B2 Comparing responses to climate variability among nearshore, shelf and oceanic regions

***Co-Convenors:***
*Jürgen Alheit (Leibniz Institute for Baltic Sea Research, Germany)*
*Vladimir Radchenko (Sakhalin Research Institute of Fisheries and Oceanography, Russia)*

Over the last two decades, convincing evidence has been collected that global and regional climate variability is a strong driving force of changes in marine ecosystems (and the fish and shell fish populations embedded in them). Climate drivers influence near-shore, shelf and oceanic regions. However, the same climate signal may be correlated with different responses of marine populations among these regions, due to the different mechanisms by which climate variability impacts these communities and the role of human activities in modifying these mechanisms, particularly in near-shore areas. Whereas the effect of climate variability has been intensely studied in single marine systems or on single species/species groups across different systems, comparisons of climatic influences on coastal and oceanic systems are generally lacking. As marine ecosystems are not amenable to experimental investigations with respect to climate effects, comparative analyses are the best way to enhance our knowledge on the response of ecosystems and their populations. Ecosystem regime shifts and teleconnection patterns in the reaction of distant marine ecosystems towards climate impacts are important phenomena which help us to better understand responses to climate variability. The goal of this session is to (1) discuss the interactions, ramifications, and potential connections between climate variability and marine ecosystems, and (2) demonstrate the impact of climate variability with a view to future climate change.

**Wednesday, April 28 (9:00-13:15)**

| | |
|---|---|
| 9:00 | ***Introduction by Convenors*** |
| 9:05 | **Svein Sundby (Invited)**<br>Changes in productivity of marine ecosystems from low to high latitudes under climate variability and change (B2-6213) |
| 9:30 | **Jae Bong Lee and Bernard A. Megrey**<br>On the utility of self-organizing maps (SOM) and k-means clustering to characterize and compare low frequency spatial and temporal climate impacts on marine ecosystem productivity (B2-6225) |
| 9:45 | **Elvira S. Poloczanska, Keith Brander, Chris Brown, John Bruno, Lauren Buckley, Michael T. Burrows, Carlos Duarte, Pippa Moore, Mary O'Connor, John Pandolfi, Camille Parmesan, Maria Sanchez-Camacho, David Schoeman, William J. Sydeman and Anthony J. Richardson**<br>Marine climate change impacts: Out of sight but not out of mind (B2-6278) |
| 10:00 | **Thomas A. Okey, Jameal F. Samhouri, Cameron H. Ainsworth, D. Shallin Busch and William L. Cheung**<br>Potential impacts of climate change on Northeast Pacific marine ecosystems (B2-6261) |
| 10:15 | **Kenneth Drinkwater and the RECLAIM Team**<br>Ecosystem response to future climate change in the Northeast Atlantic: Results from the RECLAIM Project (B2-6244) |
| 10:30 | **Susa Niiranen, Thorsten Blenckner and Reinette Biggs**<br>Are general mechanisms found behind regime shifts across marine ecosystems? (B2-6188) |
| 10:45 | ***Coffee/Tea Break*** |
| 11:05 | **Nicholas K. Dulvy (Invited)**<br>Housing crisis: Climate change-induced habitat loss impacts on temperate and tropical fishes (B2-6054) |

11:30 **Lisa B. Eisner, Seth Danielson, Edward W. Farley, Jeanette Gann and Markus Janout**
Spatial and interannual variability in oceanography, plankton and forage fish in the Bering Sea: Results from U.S. BASIS surveys for 2002-2008 (B2-6043)

11:45 **Anatoliy Ya. Velikanov**
Climatic trends and long-term changes in species composition and abundance of pelagic fishes along the Sakhalin coast in the Japan Sea and the Okhotsk Sea (B2-6012)

12:00 **Miguel Ñiquen and Cecilia Peña**
Response of dominant species in coastal and oceanic regions of Peru (B2-6296)

12:15 **Jürgen Alheit**
The limits for forecasting fish population dynamics under changing climate scenarios: The example of small pelagic fishes (B2-6247)

12:30 **Konstantin Rogachev**
Thermal limits and coastal migration of chum salmon (*Oncorhynchus keta*) determined by submesoscale circulation (B2-6023)

12:45 **Hideaki Kidokoro, Norio Yamashita, Tsuneo Goto and Yongjun Tian**
Changes in the stock size and life history traits of Japanese common squid *Todarodes pacificus* in relation to climate changes, with special comparison between in the Kuroshio-Oyashio currents region and the Sea of Japan (B2-6228)

13:00 **Brian J. Rothschild**
Coupling between multi-decadal transients in fish stock abundance and anthropogenic forcing (B2-6397)

13:15 Session ends

## Posters

B2-6006 **Vladimir B. Darnitskiy and Maxim A. Ishchenko**
Short-period variability of oceanologic conditions in the vicinity of the Pulkovskaya seamount (Part I)

B2-6007 **Vladimir B. Darnitskiy and Maxim A. Ishchenko**
Short-period variability of oceanologic conditions in the vicinity of the Pulkovskaya seamount (Part II)

B2-6072 **Olga Hernandez, Patrick Lehodey, Inna Senina, Arnaud Bertrand, Ramiro Castillo, Vincent Echevin and Philippe Gaspar**
Modelling anchovy population in the Humboldt upwelling system

B2-6088 **Svetlana Yu. Glebova**
Change in character of winter cyclonic activity over the Asian-Pacific region in 1996-2009 and its influence on a thermal regime of the Far East Seas

B2-6132 **Boris Prischepa, Oleg Titov and Yuri Lepesevich**
Climate change and prospects of fisheries in the Barents Sea and adjacent Arctic seas

B2-6137 **Jennifer Menkel and William T. Peterson**
Response of krill to climate change in the California current: Temporal and spatial variations in population “hotspots”

B2-6163 **Rubén Rodríguez-Sánchez, Héctor Villalobos and Sofía Ortega-García**
Spatial dynamics of small pelagic fish in the California Current system on the regime time-scale: Parallel processes in other species-ecosystems

B2-6186 **Kosei Komatsu, Arisa Yamawaki, Daisuke Ambe, Takahiko Kameda, Takashi Setou and Manabu Shimizu**
Impacts of mesoscale variations of water masses on larval survival processes of pelagic fishes around the Kuroshio based on an eddy resolving ocean ecosystem model

B2-6198 **Sean Lucey and Janet A. Nye**
Shifting species assemblages within the Northeast US Large Marine Ecosystem

B2-6248 **Jürgen Alheit and 12 co-authors**
Reaction of northern hemisphere ecosystems to the climate events in the late 1980s: A comparison of regime shifts and teleconnection patterns

B2-6271 **Chun Li Liu and Dan Ling Tang (*Cancelled*)**
Distribution variation of phytoplankton effect by typhoon winds in the South China Sea

B2-6320 **Daisuke Ambe, Kosei Komatsu, Manabu Shimizu, Akira Okuno and Akinori Takasuka**
Environmental temperature impacts on the early survival process of larval Japanese sardine

B2-6373 **Jay O. Peterson and William T. Peterson**
Evidence of climate change in the northern California Current ecosystem and its impact on the distribution and community composition of zooplankton

B2-6392 **Takashige Sugimoto and Masato Niki**
Long-term variations in the catch of sergestid shrimp in Suruga Bay induced by variations in the Kuroshio path and climate regime shifts

# C1 Impacts on fisheries and coastal communities

***Co-Convenors:***
*Keith Brander (National Institute of Aquatic Resources, Technical University of Denmark, Denmark)*
*Suam Kim (Pukyong National University, Korea)*

Climate change has had an impact on fisheries and coastal communities throughout history, due to environmentally driven fish stock fluctuations, changes in species distribution, extreme events and changes in sea-level. The survival of coastal communities depended on being able to cope with such changes, by altering their fishing practices or switching to alternative livelihoods. In many cases communities did not survive or suffered economic hardship and emigration. Although some adaptability can be expected in response to anthropogenic climate change, the new situation is different in a number of ways. The expected rate of change is rapid and in one direction; most fisheries are already under pressure from overfishing, habitat degradation and other sea and coastal uses; new pressures arise from sea-level rise and ocean acidification. This session will focus on forecasts of expected impacts of climate change on the coastal fish stocks and the communities that depend on them as well as strategies for survival under a changing climate.

**Wednesday, April 28 (9:00-13:00)**

| | |
|---|---|
| 9:00 | ***Introduction by Convenors*** |
| 9:05 | **R. Ian Perry, Manuel Barange, Francisco E. Werner, Eileen Hofmann and Rosemary Ommer (Invited)**<br>Adapting marine social-ecological systems to a world of change: Lessons from the GLOBEC experience (C1-6210) |
| 9:30 | **Sujan Saha**<br>Postlarvae fishing, biodiversity and livelihoods under climate change: A case study on southwest coastal community in Bangladesh (C1-6310) |
| 9:45 | **Eva Papaioannou, Athanasios Vafeidis, Jörn O. Schmidt and Martin F. Quaas**<br>Modeling the spatial distribution of coastal fisheries of the Baltic Sea using Geographic Information Systems (C1-6340) |
| 10:00 | **Ming-An Lee, Kuo-Wei Lan, Kuo-Ten Lee and Yi Chang**<br>Satellite observation on the cold water intrusion related to the exceptional fishery disaster during the ENSO events in the Taiwan Strait (C1-6174) |
| 10:15 | **Audrey J. Geffen, Arild Folkvord, Hans Høie, Anne Karin Hufthammer, Carin Andersson, Kjell Nedreaas and Ulysses S. Ninemann (presented by Mei-Yu Chang)**<br>High latitude climate variability and its implications for fish resources as revealed by fossil otoliths of cod (*Gadus morhua*) (C1-6201) |
| 10:30 | **Tatiana Krupnova, Yury I. Zuenko, Vladimir Matveev, Irina Tsypysheva and Vladimir Pavlyuchkov**<br>Reconstruction of bottom phytocenoses on the coast of Primorye caused by climate change (C1-6233) |
| 10:45 | ***Coffee/Tea Break*** |
| 11:05 | **Kevern L. Cochrane, Tarub Bahri, Cassandra de Young and Doris Soto (Invited)**<br>Evolution in an instant: Adaptation and resilience to climate change in fisheries (C1-6400) |
| 11:30 | **Akhmad Fauzi, Subandono Diposaptono and Suzy Anna**<br>Socio-economic impacts of climate change on coastal communities: The case of the north coast of Java small-pelagic fisheries (C1-6124) |

11:45 **Janet C. Coetzee, Kobus Agenbag, Carl van der Lingen, Larry Hutchings, Jan van der Westhuizen, Awie Badenhorst and Mike Copeland**
Impacts of changing weather patterns on the efficiency of South Africa's purse-seine fishery (C1-6351)

12:00 **Jong Hee Lee, Jae Bong Lee, Young Min Choi and Chang Ik Zhang**
Detecting decadal changes in marine environmental characteristics and fishery resources in Korean waters (C1-6166)

12:15 **Eider Andonegi, Jose Antonio Fernandes, Iñaki Quincoces, Xabier Irigoien, Daniel Howell and Gunnar Stefansson**
The potential use of a Gadget model to predict stock responses to climate change in combination with Bayesian networks: The case of the Bay of Biscay anchovy (C1-6236)

12:30 **Asuncion De Guzman, Cesaria Jimenez, Angelo Macario, Juliet Madula and Jayrald Santamnina**
Shifts in species abundance of sardine fisheries in southern Philippines: Early signs of vulnerability to climate change? (C1-6197)

12:45 **Nhung T.H. Nguyen and Hien T.H. Than**
Challenge and opportunity of climate change: Case studies in Vietnamese coastal communities (C1-6304)

13:00 Session ends

## Posters

C1-5998 **Maria Rebecca A. Campos**
Assessment of adaptation responses of coastal communities in the Philippines to the impacts of climate change

C1-6040 **Dmitry A. Galanin, V.A. Sergeenko and A.R. Repnikova**
Status of short-spined sea urchin (*Strongylocentrotus intermedius*) colonies and kelp (*Laminaria japonica*) thicket along southwestern Sakhalin coast

C1-6116 **K.J. Thara, R. Sajeev and T. Pankajakshan**
Impacts of ENSO and IOD on summer monsoon rainfall and oil sardine fishery along the west coast of India

C1-6146 **Julius I. Agboola**
Loss of mangrove wetlands and implications for climate change, fisheries and food security in Lagos coastal lagoons shorelines (West Africa)

C1-6147 **Mark Prime, Ralf Bublitz, Bob Houghton and Magnus Johnson**
The effect of climate change upon the inshore fisheries of the United Kingdom

C1-6242 **Tomoaki Goto**
Trends of coastal fisheries in Iwate Prefecture, Pacific coast of northern Japan, with relation to the long-term oceanographic fluctuations

C1-6257 **Jin Koo Kim, Gi-Sik Min, Moon-Geun Yoon and Yeonghye Kim**
Mitochondrial and microsatellite DNA structure of the small yellow croaker, *Larimichthys polyactis* (Pisces: Sciaenidae) in the Yellow and East China Seas

C1-6265 **Melissa Nursey-Bray, Gretta Pecl, Stewart Frusher, Caleb Gardner, Marcus Haward, Alistair J. Hobday, Sarah Jennings, André E. Punt, Hilary Revill and Ingrid van Putten**
Contesting views or collaborative opportunity? Risk perception, science and fisheries management, Tasmania, Australia

C1-6284 **Suam Kim, Sangwook Yeh, Chung-Il Lee, Sukyung Kang, Hyunwoo Kang, Jin-Hee Yoon, Jung J. Kim and Sinjae Yoo**
Forecasting practice on the common squid (*Todarodes pacificus*) population responding climate/ oceanographic changes

C1-6309 **Jung Hwa Ryu, Jin Koo Kim and Dong Seon Kim**
Fluctuation on fish fauna in the east southern sea of Korea during 2006-2009

C1-6378 **Salvador Lluch-Cota, René Kachok and María Verónica Morales-Zárate**
Reasons for high vulnerability of coastal fishing communities of Baja California (Mexico) and potential adaptation strategies to climate change

# C2 Evaluating human responses, management strategies and economic implications

***Co-Convenors:***
*Kevern Cochrane (Fishery Resources Division, Food and Agriculture Organization)*
*Jake Rice (Ecosystem Science Directorate, DFO, Canada)*

Humans depend on the oceans for many goods and services essential to their well-being. As terrestrial and marine ecosystems change in response to climate, these dependencies are expected to become even greater, particularly, but hardly exclusively, for food security. This session will focus on how society, at a range of scales from community to population, might adapt to the changes expected in the oceans, and in the goods and services on which they depend so that optimal benefits may be obtained without unacceptable increases in the risks to the systems. Contributions from social scientists, economists, and policy experts are welcomed, as well as from natural scientists interested in strategies for sustainable use of marine resources in the face of changing human needs as well as changing ocean conditions. Just a few decades in the future, societies and governments may face very difficult choices about the proper balance between provision of food security and conservation of marine biodiversity for an even bigger human population confronted with changing, possibly declining, aquatic and terrestrial food production. The proper balance between established uses of oceans and coastal regions and new uses, such as wind and tidal power, must also be faced. This session is intended to open an expert dialogue on these important questions, through a mixture of conceptual, analytical, and case-history presentations.

**Wednesday, April 28 (14:30-18:30)**

14:30 ***Introduction by Convenors***

14:35 **Bonnie J. McCay (Invited)**
Surfclam dramas and other stories about the human dimensions of climate change and fisheries (C2-6018)

15:00 **Serge M. Garcia, Andrew A. Rosenberg and Jake Rice**
Food security, fisheries, and climate change (C2-6021)

15:15 **Gretta Pecl, Rebecca Brown, Peter Walsh, Stewart Frusher, Graham Edgar, Jeremy Lyle, Elvira S. Poloczanska and Rick Stuart-Smith**
Citizen science as a research tool for monitoring ecological change in the marine environment (C2-6282)

15:30 **Renae C. Tobin and Stephen G. Sutton**
Will diversity assist adaptability? A case study contrasting diverse and specialized fishing sectors in the Queensland Inshore Fishery, Australia (C2-6300)

15:45 **Ikutaro Shimizu, Tsutomu Ohnuki and Kunio Abe**
Economic strategies for avoiding climate change effects on Japanese salmon fisheries (C2-6098)

16:00 ***Coffee/Tea Break***

16:20 **Johann D. Bell (Invited)**
Climate change, fisheries and aquaculture in the Pacific – Implications for food security, livelihoods and economic growth (C2-6185)

16:45 **Milena Arias-Schreiber, Miguel Ñiquen and Marilou Bouchon**
Adapting to climate change – Lessons from the Peruvian anchovy fishery on how to cope with extreme climatic events and environmental variability (C2-6346)

17:00 **Satsuki Takahashi**
In search of new sea legs: Women's roles in the survival of Japan's fishing industry (C2-6122)

17:15 **Henry P. Huntington, Alpina Begossi and Renato A.M. Silvano**
Traditional fisheries practices and adaptation to environmental change: Case studies from Alaska and Brazil (C2-6055)

17:30 **Renato A.M. Silvano, Henry P. Huntington and Alpina Begossi**
Fishers' local ecological knowledge about fish and climatic change (C2-6318)

17:45 **Friday J. Njaya**
The Lake Chilwa fishing household strategies in response to water level changes: Migration and conflicts (C2-6129)

18:00 **Pedcris M. Orencio and Masahiko Fujii**
Building community adaptability through ecosystem approach planning in the Province of Aurora, Philippines (C2-6159)

18:15 **Sahri Muhammad, Pudji Purwanti and Aida Sartimbul**
Household fishermen empowerment based on local community wisdom as a problem solver on fishermen poverty: Case study in Madura Strait, Indonesia (C2-6207)

18:30 Session ends

## Posters

C2-6086 **Siyanbola Adewumi Omitoyin, Tosan Fregene and Dontsop Paul**
Impact of climate change on livelihood and food security of artisanal fisherfolks in Lagos State, Nigeria

C2-6140 **Francois Bastardie, J. Rasmus Nielsen, Bo Sølgaard Andersen and Ole Eigaard**
Modeling energy consumption efficiency of fisheries: What to gain by effort displacement? The case of Danish Skagerrat-Kattegat fisheries

C2-6155 **Michael D. Pido, Ruth Guzman, Maripaz L. Perez, Elvira Martija, Elen R. Basug and Len R. Garces**
The role of the academe in undertaking research and developing management strategies to address climate change impacts on fisheries: Some examples of initiatives of academic institutions in the Philippines

C2-6169 **Ingrid L. Holliday**
"Bringing it all together" – A multi-disciplined, collaborative approach to preparing fisheries and aquaculture for climate change in South Eastern Australia

C2-6172 **Felipe Hurtado-Ferro, Sachihiko Itoh and Kunio Shirakihara**
Could management react to a changing climate? The case of the Japanese small pelagic fishes

C2-6178 **I Nyoman Radiarta, Sei-ichi Saitoh and Toru Hirawake**
Potential impacts of climate change on Japanese scallop aquaculture: A case study in Funka Bay, Hokkaido, Japan

C2-6281 **Neil Holbrook, Gretta Pecl, Alistair J. Hobday and Stewart Frusher**
Australian National Climate Change Adaptation Research Network for Marine Biodiversity and Resources

# D2 Contemporary and next generation climate and oceanographic models, technical advances and new approaches

***Co-Convenors:***
*Jonathan Hare (Northeast Fisheries Science Center, NMFS/NOAA, USA)*
*Shin-ichi Ito (Tohoku National Fisheries Research Institute, FRA, Japan)*

The projection of marine ecosystem response to future climate scenarios is needed to assess and implement marine ecosystem management. The marine ecosystem is part of the earth system, and prediction of ecosystem responses requires integrated knowledge from physical, chemical, and biological perspectives, as well as from marine, terrestrial and atmospheric perspectives. The earth system is complex with non-linear feedbacks (including biological to physical), regime shifts, and, in some cases, thresholds beyond which change is irreversible. Therefore, the uncertainties of climate and oceanographic models cause uncertainties of the projection of marine ecosystem response not only directly but also through complex feedback mechanisms. To reduce the uncertainties of the marine ecosystem projection, we must understand the mechanisms controlling climate systems and the linkages to marine ecosystems. Specific species responses to future ecosystem conditions are required by natural resource managers, and these require specific information (*e.g.*, environments in coastal area during the short spawning period) as well as information regarding change of the ecosystem as a whole (*e.g.*, total primary production, food-web dynamics). These issues are not part of climate modeling, but mechanistic links between the biological, physical, and chemical systems must be identified and incorporated into coupled population-ecosystem-climate models. Technical advances and new approaches are essential to achieve the goal of producing better projections of marine ecosystem response to future climate scenarios. This session will focus on climate and oceanographic models, including modeling of climate and ecosystem interaction, and technical advances and new approaches.

## Wednesday, April 28 (14:30-18:30)

14:30 ***Introduction by Convenors***

14:35 **Michio Kawamiya (Invited)**
Global change projection for ocean biogeochemistry and ecosystem (D2-6117)

15:00 **Masami Nonaka, Bunmei Taguchi, Hideharu Sasaki and Hisashi Nakamura**
Decadal variability in the oceanic frontal zones in the western North Pacific Ocean in an eddy-resolving OGCM (D2-6325)

15:15 **Georgina A. Gibson, Kate Hedström, Enrique N. Curchitser and Albert J. Hermann** (D2-6209)
Simulating lower trophic level ecosystem dynamics in the Bering Sea

15:30 **Yasumasa Miyazawa, Xinyu Guo, Ruo Chao Zhang, Sergey M. Varlamov, Tomowo Watanabe, Takashi Setou and Daisuke Ambe**
Roles of the in-situ observations in the detection of the Kuroshio frontal variability south of Japan (D2-6324)

15:45 **Enrique N. Curchitser, Kate Hedström, William Large and Jon Wolf**
From a climate to a multi-scale earth system model: Technical issues and advances (D2-6357)

16:00 ***Coffee/Tea Break***

16:20 **Anand Gnanadesikan (Invited)**
Climate models and fisheries: Opportunities and challenges (D2-6123)

16:45 **Kosei Komatsu, Naoki Yoshie, Shin-ichi Ito, Takahiko Kameda, Tsuneo Ono, Kiyotaka Hidaka, Toru Hasegawa, Akira Kuwata, Miwa Nakamachi, Yuji Okazaki, Takeshi Okunishi, Kazuaki Tadokoro, Hiroaki Saito and Yasuhiro Yamanaka**
Interannual variations of 3D structures of lower-trophic-level ecosystems in the western North Pacific using a new marine ecosystem model based on an eddy-resolving data-assimilative OGCM (D2-6323)

17:00 **Francisco E. Werner, Peter H. Wiebe and Jonathan A. Hare**
Developing a modeling framework for basin scale models of marine ecosystems (D2-6348)

17:15 **Michio J. Kishi, Shin-ichi Ito, Bernard A. Megrey, Kenneth A. Rose and Francisco E. Werner**
A review of the NEMURO.FISH model application to marine ecosystem investigations and its ability to evaluate responses of fish to future climate change (D2-6298)

17:30 **Scott Condie, Mark Hepburn, Jim Mansbridge and Phillip England**
A second generation online tool for exploring oceanographic connectivity (D2-6051)

17:45 **Ülo Suursaar, Markus Vetemaa and Tiit Kullas**
Climate change induced decadal variations in hydrodynamic conditions in the Estonian coastal waters and their possible influence on fish (D2-6131)

18:00 **William Peterson, Hongsheng Bi, Cheryl A. Morgan and Edmundo Casillas**
The Pacific Decadal Oscillation and marine food webs in the northern California Current: Variations in source waters which feed the California Current may be the mechanism which links climate change with ecosystem response (D2-6384)

18:15 **Maria A. Gasalla, O. Sato and P.S. Polito**
An application of the ethno-oceanographic framework to study global change issues off the South Brazil Bight with remote-sensing data (D2-6388)

18:30 Session ends

## Posters

D2-6093 **Hui Wang, Guimei Liu, Fei Chai, Xingyu Song and Shan Gao (*Cancelled*)**
Climate change and the ecosystem response in the South China Sea: Observations and numerical investigations

D2-6104 **Aleksey V. Koldunov**
Variability of the biotic material flow divergence patterns of the Azores

D2-6177 **Taketo Hashioka, Takashi T. Sakamoto, Hiroshi Sumata, Takeshi Okunishi, Masahito Shigemitsu, Maki N. Aita, Naoki Yoshie, Naosuke Okada, Akio Ishida and Yasuhiro Yamanaka**
Potential impact of global warming on North Pacific spring blooms projected by an eddy-permitting 3-D ocean ecosystem model

D2-6192 **Tatsuro Watanabe, Katsumi Takayama, Hideyuki Kawamura and Iori Tanaka**
One dimensional ecosystem model in the northern Japan Sea based on an operational ocean forecast system

D2-6256 **Naoki Yoshie, Kosei Komatsu, Shin-ichi Ito, Takahiko Kameda, Tsuneo Ono, Kiyotaka Hidaka, Toru Hasegawa, Akira Kuwata, Miwa Nakamachi, Yuji Okazaki, Takeshi Okunishi, Kazuaki Tadokoro, Hiroaki Saito and Yasuhiro Yamanaka**
Dynamics of lower-trophic-level ecosystems in the western North Pacific simulated by a high resolution 3D ecosystem model

D2-6277 **Takeshi Okunishi, Shin-ichi Ito, Naoki Yoshie, Taketo Hashioka, Hiroshi Sumata and Yasuhiro Yamanaka**
The impact of density-dependent processes on geographical distribution of Japanese sardine (*Sardinops melanostictus*)

D2-6322 **Hiroaki Tatebe, Masayoshi Ishii, Masahide Kimoto, Takashi T. Sakamoto, Yoshiki Komuro and Takashi Mochizuki**
Interannual to decadal modulations of high frequency eddies in the Kuroshio-Oyashio confluence zone in a high-resolution CGCM with ocean data assimilation

D2-6337 **Takashi T. Sakamoto, Yoshiki Komuro, Masayoshi Ishii, Hiroaki Tatebe, Akira Hasegawa, Hideo Shiogama, Takahiro Toyoda, Masato Mori, Seita Emori, Hiroyasu Hasumi and Masahide Kimoto**
MIROC4.0 – A high-resolution AOGCM for the near-term climate prediction

# GP General Poster Session

GP-5783 **Vladimir B. Darnitskiy and Maxim A. Ishchenko**
Kuroshio System – The quasi-cyclic dynamics and the bifurcation from the source to the Shatskikiy hills

GP-6084 **Chiara Papetti, Mario La Mesa, Jennifer Rock, Esteban Barrera-Oro, Tomaso Patarnello and Lorenzo Zane**
Contrasting pattern of genetic differentiation between two Antarctic Channinchthyidae fish species at the West Antarctic Peninsula

GP-6134 **Minoru Tomiyama and Teruhisa Komatsu**
The influence of seawater temperature on sandeel stock in Ise Bay

GP-6193 **Eleuterio Yáñez and María Angela Barbieri**
Climate change and fisheries in Chile

GP-6204 **Aida Sartimbul, Hideaki Nakata and Erfan Rohadi**
Chlorophyll *a* concentration dynamics due climate change and its possible impact on pelagic fishes at Java and Bali, Indonesia: Case study in 2006

GP-6205 **Oky Rosita Tanjung, Aida Sartimbul and Anthon Efani**
The implication of oceanographic and meteorological factors on algae blooming events and possible impact on the *Sardinella lemuru* fishery along the coast of Bali, Indonesia

GP-6206 **Sary Rahmawati, Aida Sartimbul and Daduk Setyohadi**
Biological aspects and population dynamics of mud crab (*Scylla serrata*) in the mangrove area of Curah Sawo, Probolinggo, Indonesia

GP-6326 **Chia-Hui Wang and Hui-Lun Chen**
Biological studies of the oval squid *Sepioteuthis lessoniana* population in northern Taiwan

GP-6327 **Kazumi Sakuramoto, Satomi Shimoyama and Naoki Suzuki (*Cancelled*)**
Forecasting models in the recruitment of Japanese sardine, *Sardinops melanostictus*, in the northwestern Pacific, incorporating environmental conditions and evaluations of management effects

GP-6332 **Naoki Suzuki and Kazumi Sakuramoto**
Effect of measurement errors on model selection in analyses of the stock–recruitment relationship

GP-6369 **Luis A. Cubillos, Leonardo R. Castro and Gabriel Claramunt**
Fishery-induced changes on the reproductive cycle of two small pelagic fish off central Chile

GP-6410 **Dmitry D. Kaplunenko, Vyacheslav B. Lobanov, Alexander Yu. Lazaryuk, Pavel Ya. Tishchenko and Vladimir A. Zvalinsky**
Measurements of $NO_3$ saturation in the Japan Sea by *in situ* and hydrochemical methods

GP-6412 **Jingfeng Fan, Gengchen Han, Chuanlin Huo, Xinzhen Lin and Chunjiang Guan (*Cancelled*)**
Response of zooplankton and phytoplankton to climate change in China

# W1 Reducing global and national vulnerability to climate change in the fisheries sectors: Policy perspectives post Copenhagen

***Co-Convenors:***
*Cassandra de Young (Food and Agriculture Organization)*
*Eddie Allison (WorldFish Center, Malaysia on behalf of the Global Partnership on Climate, Fisheries and Aquaculture (PaCFA))*

The challenges of climate change are a top priority for world leaders. About 520 million people—8% of the world's population—depend on fisheries and aquaculture as a source of protein, income, or family stability, many of them from vulnerable communities in tropical and low-lying areas and Small Island Developing States. The countries that are most vulnerable to climate change impacts on their fisheries are among the world's poorest, whose inhabitants are twice as dependent upon fish for food as those of other nations, with 27% of dietary protein derived from fish compared with 13% elsewhere (Allison *et al.* 2009).

The Global Partnership on Climate, Fisheries and Aquaculture (PaCFA) was created in 2009 to encourage states to include aquatic ecosystems, fisheries and aquaculture issues when formulating action to combat climate change, particularly in the build up to the UN Framework Convention on Climate Change (UNFCC) COP15 meeting in Copenhagen, December 2009. PaCFA recognizes that many governmental, non-governmental and civil society organizations have become actively engaged in the search for improved knowledge of the likely impacts of climate change on fisheries and aquaculture (Cochrane *et al. 2009*) and providing assistance to countries and communities to develop policies and strategies for adaptation and development of resilience to likely changes. However, these actions tend to take place in isolation from each other with a minimum of communication, sharing of experiences and cooperation. The role of PaCFA is to increase the effectiveness of these actions through increased collaboration, complementing mandates and capabilities of each organization and maximising the effectiveness of joint efforts.

The objectives of this workshop are to (1) present the goals and strategy of PaCFA; (2) inform participants about the COP15 decisions regarding adaptation and mitigation actions relevant to the reduction of vulnerability to climate change impacts on fisheries, aquaculture and marine ecosystems – including built-in mechanisms to do so within the UNFCCC; (3) consider the responses of individual agencies and institutions to COP-15 and any adaptation and mitigation efforts in response to climate changes; (4) discuss how the PaCFA can assist national and multinational agencies reduce the vulnerability of countries and regions to climate change impacts on fisheries and marine ecosystems, with particular emphasis on LDC and small island states; (5) identify the critical gaps in the science underpinning climate impacts on fish production systems and marine and coastal ecosystems and on potential adaptation.

This workshop will discuss and prepare a Plan of Action in pursue of these objectives. A policy note on next steps and needs to develop the objectives of PaCFA will be considered. The workshop may also produce a paper for the Symposium volume summarizing the current state of policy decisions regarding adaptation and mitigation actions relevant to the reduction of vulnerability to impacts of climate change on fisheries and marine ecosystems, and an analysis of the quality of the science base (including social sciences) that underpins these decisions.

**Sunday, April 25 (9:00-12:30)**

| | |
|---|---|
| 9:00 | ***Introduction by Convenors*** |
| 9:10 | Discussion |
| 10:30 | ***Coffee/Tea Break*** |
| 10:50 | Discussion |
| 12:30 | Workshop ends |

## Posters

W1-6368 **Jose M.P. Silva, Miguel J.A. Lopes and Ana R.P. Quintas (*Cancelled*)**
Marine ecosystem reestablishment − Seawater electrolyse with carbon capture

W1-6403 **Hasan M. Abdullah and Yoshio Awaya**
Monitoring the impact of climate change on inland water bodies and fisheries by remote sensing and GIS technique a case study of Chalan beel (Bangladesh)

# W2 Potential impacts of ocean acidification on marine ecosystems and fisheries

***Co-Convenors:***
*Kenneth L. Denman (Canadian Centre for Climate Modelling and Analysis; DFO, Canada)*
*Yukihiro Nojiri (National Institute for Environmental Studies, Japan)*
*Hans Pörtner (Alfred-Wegener Institute, Germany)*

The global ocean is being acidified as carbon dioxide from fossil fuel emissions enters its surface waters. The magnitude of this increase is directly related to the amount of carbon dioxide added, and more certain than many other changes related to climate change. Predicting the impacts of increasing acidification on marine ecosystems and fisheries is difficult due to the lack of knowledge of the ability of individual species and functional groups to adapt to increasing acidification, especially in combination with related effects associated with climate change such as increasing temperature, declining dissolved oxygen (Brewer and Peltzer, 2009), and stratification. Hence, potential effects cannot yet be represented in models of marine ecosystems. Potential impacts on commercial fisheries are significant: an analysis of 2007 US 'at vessel' fisheries value indicates 73% of the value is associated with calcium carbonate organisms and their direct predators (Cooley and Doney, 2009).

This workshop will discuss manipulation experiments and observations on the effects of high acidity (low pH) caused by elevated carbon dioxide on organisms at all trophic levels of fisheries foodwebs, modelling approaches to predict the impact of continuing increases in atmospheric carbon dioxide, effects on marine biodiversity, and economic and social impacts on marine fisheries.

It is expected that the workshop will produce a white paper on these research directions and a summary article in PICES Press.

## Sunday, April 25 (9:00-15:45)

| | |
|---|---|
| 9:00 | ***Introduction by Convenors*** |
| 9:05 | **Kenneth L. Denman, James Christian, Nadja Steiner and Warren Lee**<br>Acidification of the global ocean: Observational evidence and projections to 2100 with the Canadian Earth System Model (CanESM) (W2-6370) |
| 9:20 | **Masako Nakamura, Shun Ohki, Atsushi Suzuki and Kazuhiko Sakai**<br>Metabolism and metamorphosis of coral larvae in acidified seawater (W2-6149) |
| 9:35 | **Lailah G. Lartey-Antwi and Andreas J. Andersson**<br>Effects of ocean acidification on the growth of the flat-tree oyster, *Isognomon alatus* (Gmelin, 1791) (W2-6259) |
| 9:50 | **Ryota Suwa and Yoshihisa Shirayama**<br>Effects of diurnal $pCO_2$ fluctuation on sea urchin larvae: A preliminary report (W2-6361) |
| 10:05 | **Haruko Kurihara**<br>Overview of the impacts of ocean acidification on the early development of fishes and shellfishes (W2-6303) |
| 10:20 | ***Coffee/Tea Break*** |
| 10:40 | **Awantha Dissanayake, Atsushi Ishimatsu, Haruko Kurihara and So Kawaguchi**<br>Climate change impacts (ocean acidification and temperature) on the metabolic scope and activity of nektonic organisms: A crustacean example (W2-6311) |
| 10:55 | **Kehinde Salau**<br>Mathematical approach to modeling the effects of ocean acidification on the pteropod and pink salmon population (W2-6243) |

| | |
|---|---|
| 11:10 | **Atsushi Ishimatsu, Atsuko Fukuda and Haruko Kurihara**<br>Effects of $CO_2$-driven ocean acidification and warming on early development of fish (W2-6291) |
| 11:25 | **Philip L. Munday, Monica Gagliano, Simon Thorrold, Jennifer M. Donelson and Danielle L. Dixson**<br>Ocean acidification does not affect the early life history development of a tropical marine fish (W2-6128) |
| 11:40 | **David M. Checkley, Jr.**<br>Effects of elevated $pCO_2$ on fish otoliths – Results, inference, and experimental design (W2-6390) |
| 11:55 | Short Introduction Posters (3 min. each) |
| 12:30 | ***Lunch*** |
| 14:00 | Poster viewing session (60 min) |
| 15:00 | Closing Discussion |
| 15:45 | Workshop ends |

## Posters

| | |
|---|---|
| W2-6065 | **Steven S. Rumrill, Alicia R. Helms and Adam S. DeMarzo**<br>Variability in pH values and the potential influence of ocean acidification on oysters and other shellfish in Pacific Northwest estuaries |
| W2-6237 | **Koji Sugie, Hisashi Endo, Koji Suzuki and Takeshi Yoshimura**<br>Increase in the Si:N drawdown ratio of the Bering Sea phytoplankton community under high $CO_2$ and iron-limited conditions |
| W2-6249 | **Hideki Takami, Ryo Kimura, Tsuneo Ono, Toshihiro Onitsuka and Yukihiro Nojiri**<br>Effects of ocean acidification on the early developmental stages of Ezo abalone *Haliotis discus hannai* |
| W2-6287 | **Jun Kita**<br>Impact of a high-$CO_2$ environment on Japanese Ivory-shell, *Babylonia japonica* |
| W2-6288 | **Umme Salma and Hyun Woo Kim**<br>Effects of $CO_2$ induction on development of Brine Shrimp (*Artemia franciscana*) |
| W2-6344 | **Bo Kwang Kim and Hyun Woo Kim**<br>Molecular technique analysis of effect of ocean acidfication on brine shrimp |
| W2-6422 | **Will Le Quesne and John K. Pinnegar**<br>Physiology to Fisheries: Starting steps and future approaches |

# W3 Coupled climate-to-fish-to-fishers models for understanding mechanisms underlying low frequency fluctuations in small pelagic fish and projecting its future

***Co-Convenors:***
*Salvador Lluch-Cota (Centro de Investigaciones Biologicas del Noroeste (CIBNOR), Mexico)*
*Enrique N. Curchitser (Institute for Marine and Coastal Sciences, Rutgers University, USA)*
*Shin-ichi Ito (Tohoku National Fisheries Research Institute, FRA, Japan)*

The low-frequency variability of small pelagic fish abundance is one of the most emblematic and best-documented cases of fish population fluctuations not explained wholly by fishing effort. Over the last 25 years, diverse observations have been integrated into several hypotheses; however, due to limited-duration time series, hypothesis testing has proven extremely difficult with the available statistical and empirical tools. As a result, the mechanistic basis for how the physics, biogeochemistry, and biology interact to result in the various patterns of synchronous variability across widely separated systems remains unknown. Identification of these mechanisms is necessary in order to explore projections and to build scenarios of the amplitude and timing of stock fluctuations, and their responses to human interactions (fisheries) and climate change. The workshop aims to bring and compare state-of-the-art modeling tools and discuss on expertise to tackle this important scientific and environmental problem.

The workshop will likely produce a review paper on state-of-art models for coupled physical and biological (including higher trophic level) systems. It is also expected that papers presented at the workshop will be submitted for publication in the Symposium volume.

**Sunday, April 25 (9:00-17:00)**

| | |
|---|---|
| 9:00 | ***Introduction by Convenors*** |
| 9:30 | **Ryan R. Rykaczewski**<br>Changes in mesozooplankton size structure along a trophic gradient and implications for the growth of small pelagic fish (W3-6365) |
| 9:55 | **Wolfgang Fennel**<br>A consistent nutrient to fish model for the Baltic Sea (W3-6027) |
| 10:20 | ***Coffee/Tea Break*** |
| 10:40 | **George Triantafyllou, Kostas Tsiaras, Stylianos Somarakis, Dimitris Politikos George Petihakis, Annika Pollani, Shin-ichi Ito and Bernard A. Megrey**<br>Development and implementation of a 3D-IBM in the north Aegean Sea (eastern Mediterranean) that describes the full life cycle of anchovy (W3-6297) |
| 11:05 | **Shin-ichi Ito, Takeshi Okunishi, Michio J. Kishi and Muyin Wang**<br>Potential impact of climate change on Pacific saury (W3-6267) |
| 11:30 | **Kate Hedström, Jerome Fiechter, Kenneth A. Rose, Enrique N. Curchitser, Miguel Bernal, Shin-ichi Ito and Bernard A. Megrey**<br>Development of a climate-to-fish-to-fishers model: Data structures and domain decomposition (W3-6211) |
| 11:55 | **Kenneth A. Rose**<br>Should climate-to-fish-to-fishers models be assembled from existing models? (W3-6401) |
| 12:20 | ***Lunch*** |
| 14:00 | Discussion |
| 17:00 | Workshop ends |

# W4 Salmon workshop on climate change

***Co-Convenors:***
*James Irvine (Pacific Biological Station, DFO, Canada)*
*Masa-aki Fukuwaka (Hokkaido National Fisheries Research Institute, FRA, Japan)*
*Suam Kim (Pukyong National University, Korea)*
*Vladimir Radchenko (Sakhalin Research Institute of Fisheries and Oceanography, Russia)*
*Loh-Lee Low (Alaska Fisheries Science Center, NMFS/NOAA, USA)*
*Shigehiko Urawa (North Pacific Anadromous Fish Commission)*

The North Pacific region is home to multiple species of salmonid fishes, including anadromous Pacific salmon that regularly migrate from freshwater to the sea and back. Salmon provide economic benefits in the form of subsistence, commercial, and recreational fisheries, and contribute to the cultural enrichment of the regions where they occur. Their ecological role is complex as they facilitate energy transfer directly and indirectly at multiple trophic levels in many ecosystems. Their ability to occupy habitats in fresh, salt, and brackish water has led to a remarkable diversity of life histories, but climate change threatens to alter their distribution and abundance.

Salmon are found most frequently in cooler regions of the Pacific Ocean. In recent years, commercial catches have been among the highest on record, with no indication of declines. For instance, 2007 catches exceeded 1 million tonnes, with pink and chum salmon constituting 51 and 31% of the catch by weight respectively. Yet coho, Chinook, and some sockeye salmon populations are declining in many areas.

This one-day workshop will examine scenarios for the future of Pacific salmon, based on climate projections from coupled ocean/climate or other models or from statistical projections of expected climate changes. The workshop will emphasize regional scales that are believed to be of particular importance. For example, global warming may enhance oceanic conditions for some species in some regions, while diminishing them for others. A good understanding of potential interactions between regional physical and biological processes is critical for accurate projections of such regional responses. The workshop will provide an opportunity to examine whether the responses of salmon populations to climate change will differ among regions, and what the mechanisms might be.

It is expected that papers presented at the workshop, as well as documentation from the panel discussion, will be submitted for publication in the Symposium volume.

## Sunday, April 25 (9:00-17:30)

| | |
|---|---|
| 9:00 | ***Introduction by Convenors*** |
| 9:10 | **James R. Irvine and Masa-aki Fukuwaka**<br>Setting the stage for predicting climate change effects on Pacific salmon – How has salmon abundance varied during the last 85 years and why? (W4-6121) |
| 9:30 | **Masa-aki Fukuwaka, Toshiki Kaga and Tomonori Azumaya**<br>Regional differences in climate factors controlling chum and pink salmon abundance (W4-6096) |
| 9:50 | **Masahide Kaeriyama, Michio J. Kishi and Hyunju Seo**<br>Global warming and density-dependent effects on Hokkaido chum salmon (W4-6138) |
| 10:10 | **Ed V. Farley, Jr., Lisa B. Eisner, J. Murphy, R. Heintz and Alex Andrews**<br>Implications of a warming eastern Bering Sea on western Alaska salmon (W4-6203) |
| 10:30 | ***Coffee/Tea Break*** |
| 10:50 | **Phillip R. Mundy and Dani F. Evenson**<br>Phenolgy of high latitude chinook salmon populations (W4-6381) |

11:10 **Thomas C. Wainwright and Laurie A. Weitkamp**
Climate effects and Oregon coast coho salmon: A multi-ecosystem approach (W4-6218)

11:30 **Thomas E. Reed, Robin S. Waples, Daniel E. Schindler, Eli Meir and Nathan J. Mantua**
Adaptation and persistence of Pacific salmon facing climate change: An individual-based modeling analysis (W4-6245)

11:50 **Randall M. Peterman, Peter B. Adams, Brigitte Dorner, Douglas L. Drake, Harold J. Geiger, Kendra Holt, Chris Jordan, David P. Larsen, Steven A. Leider, Richard H. Lincoln, Anthony R. Olsen, Charles K. Parken, Jeffrey D. Rodgers and Shaun Walbridge**
The Salmon Monitoring Advisor: A hierarchical web site to help design and implement salmon monitoring programs (W4-6087)

12:10 **Larry Wasserman**
Developing salmon management responses to climate impacts at the watershed scale (W4-6222)

12:30 ***Lunch***

13:30 Short Introduction Posters (10 min each)

14:30 **Discussion**
Forecasting impacts

15:30 ***Coffee/Tea Break***

16:00 **Discussion**
Long term research priorities

17:00 Wrap Up, publication plans

17:30 Workshop ends

## Posters

W4-6048 **Cyril Piou and Etienne Prévost**
Atlantic salmon population dynamics under scenarios of climate change: An individual-based demogenetic approach

W4-6133 **Sergey Prusov, Boris Prischepa, Elena Samoylova and Svetlana Krylova**
Long-term changes in biological characteristics and abundance of Atlantic salmon juveniles and adults from important Kola Peninsula rivers (Russian Federation)

W4-6144 **Yasuyuki Miyakoshi, Mitsuhiro Nagata, Makoto Fujiwara and Sei-ichi Saitoh**
Effects of coastal seawater temperature on the return rate of hatchery-reared chum salmon in Hokkaido and recent shifts in coastal environmental conditions and release of juveniles

W4-6180 **Yukimasa Ishida, Hiroyasu Adachi, Isao Yagisawa, Kazuaki Tadokoro and Harold J. Geiger**
Archeological evidence implies that global warming will shift Japanese chum salmon distributions northward

W4-6268 **Gregory T. Ruggerone, Beverly A. Agler and Jennifer L. Nielsen**
Climate, growth, and population dynamics of western Alaska Chinook and coho salmon

# W5 Networking across global marine "hotspots"

***Co-Convenors:***
*Gretta Pecl (Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Australia)*
*Alistair J. Hobday (CSIRO Marine and Atmospheric Research, Australia)*
*Stewart Frusher (Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Australia)*
*Warwick Sauer (Rhodes University, South Africa)*

Regional global warming 'hotspots', typified by above average ocean temperature increases, provide the potential for early warning and evidence of the response by natural resources to climate change. In theory, regions at the 'front-line' of climate change should also be leading the field in terms of assessing impacts and evaluating adaptation options. Networking and synthesising outcomes from across hotspots can facilitate accelerated learning and also indicate sensible pathways for maximising adaptation and minimising impacts for other global regions.

This workshop is designed to (1) highlight where global marine 'hotspots' occur now, and where they are projected to occur in the future; (2) summarize the information currently emerging on biological climate change impacts in these areas, and (3) discuss the potential for developing a global network of scientists, policy makers and managers working in marine hotspots.

Ecological monitoring of hotspots provides us with one of the first opportunities to detect the nature and pace of climate change induced impacts on our marine ecosystems, and also the first prospect for validating species or ecosystem model projections against reality. Fisheries provide significant social and economic benefits globally, and early warning of changes in resource quality and/or availability is required to minimize social tensions (*e.g.*, increased poverty and changes in resource allocation) and societal costs (*e.g.*, income redistribution and government restructuring). Prior knowledge of how and when resources may alter will also facilitate the development, application and evaluation of adaptation options for fisheries.

Participants providing or presenting a summary of impacts from any of the global hotspots will be asked to contribute to a multi-authored publication in a high-ranking international journal. Identification of biological change in these hotspots is the main workshop challenge; however, participants are also requested to identify publications or unpublished data showing long-term change in oceanographic or physical characteristics of the area (*e.g.*, SST, currents). Several potential proposals and funding sources for a global network of marine hotspots will be discussed.

## Sunday, April 25 (9:00-17:30)

| | |
|---|---|
| 9:00 | ***Introduction by Convenors*** |
| 9:15 | **Alistair J. Hobday and Gretta Pecl**<br>Identification of global marine hotspots: Sentinels for change and vanguards for adaptation (W5-6152) |
| 9:30 | **Stewart Frusher, Gretta Pecl, Alistair J. Hobday, Craig Johnson and Zoe Doubleday**<br>Climate driven changes in marine assemblages in SE Australia: A southern hemisphere 'hotspot' (W5-6312) |
| 9:45 | **Larry Hutchings, Carl van der Lingen, Chris Reason, Frank Shillington, Andy Cockcroft, Warren Potts, Romina Novo-Henriques, Paul Shaw and Warwick Sauer**<br>The Benguela Current Large Marine Ecosystem (W5-6408) |
| 10:00 | **Graham Edgar and Stuart Banks**<br>Catastrophic changes to inshore benthic communities following oceanographic warming events in the Galapagos archipelago (W5-6321) |
| 10:15 | **Franz J. Mueter**<br>Biological responses to recent climate variability on the eastern Bering Sea shelf (W5-6307) |

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| 10:30 | ***Coffee/Tea Break*** |
| 11:00 | **Thomas A. Okey, Alvaro Montenegro, Veronica Lo, Sabine Jessen and Hussein Alidina**<br>Overview of climate change effects in British Columbia marine ecosystems (W5-6306) |
| 11:15 | **Nicholas K. Dulvy, Doug J. Beare, Julia L. Blanchard, Jan G. Hiddink, Simon Jennings, Brian J. MacKenzie and Allison L. Perry**<br>Rapid ecological change in the Northeast Atlantic climate change hotspot (W5-6416) |
| 11:30 | **Nguyen Huu Ninh**<br>Aquaculture and climate change in the coastal zone of Vietnam (W5-6341) |
| 11:45 | **Kuo-Tien Lee and Hsueh-Jung Lu**<br>Impact of climate change on coastal fishery resources of Taiwan (W5-6406) |
| 12:00 | **Wang Hui**<br>South China Sea |
| 12:15 | **Lucy Scott and Warwick Sauer**<br>Vulnerability to ocean warming in the Mozambique channel region (W5-6407) |
| 12:30 | ***Lunch*** |
| 14:00 | **Yury I. Zuenko**<br>The Japan Sea hotspot:  Impacts of warming on bio-productivity and fisheries resources (W5-6404) |
| 14:15 | **José H. Muelbert**<br>Oceanography and biological production off South Brazil and Urugay (W5-6405) |
| 14:30 | **George L. Hunt, Jr.**<br>Hotspots in warming sub-arctic seas (W5-6037) |
| 14:45 | **Group Discussion**<br>What practical functions could/should a Global Hotspots Network perform? |
| 15:30 | ***Coffee/Tea Break*** |
| 16:00 | **Group Discussion**<br>Given these functions – How should we define a network? |
| 16:30 | **Group Discussion**<br>Options to establish and develop a network – Potential frameworks and funders |
| 17:00 | **Group Discussion**<br>Outline structure of synthesis paper, feedback and action items |
| 17:30 | Workshop ends |

# W6 Examining the linkages between physics and fish: How do zooplankton and krill data sets improve our understanding of the impacts of climate change on fisheries?

***Co-Convenors:***
*William Peterson (Hatfield Marine Science Center, NMFS/NOAA, USA)*
*Kazuaki Tadokoro (Tohoku National Fisheries Research Institute, FRA, Japan)*

This workshop will provide an opportunity for those keenly interested in "how data on zooplankton and krill can be used to better understand and forecast the impacts of climate change on fisheries" to discuss the topic in an informal workshop atmosphere. It is expected that the workshop will demonstrate explicitly how information on zooplankton and krill contribute to better understanding of linkages between physics and fish. Furthermore, the workshop will likely generate novel ideas that will add to the open discussions during the Symposium itself.

It is anticipated that the workshop will produce a white paper that summarizes ongoing research activities as well as publications which link climate change to fisheries through changes in the food web in a variety of ecosystems – coastal, oceanic, upwelling, Arctic, and Antarctic. This will be a foundation document that shows where we are now and where we want to be in the future. It would also produce a set of recommendations for how we might move forward in our quest to better understand the mechanisms that link physics and fish through food chain interactions. Such a white paper could be found acceptable for publication, after peer review, in the "Horizons" section of the *Journal of Plankton Research*.

**Sunday, April 25 (13:00-17:30)**

13:00 **William T. Peterson**
Overview of some physical mechanisms that link physical forcing with zooplankton and fisheries response in the North Pacific

13:20 **Ryan R. Rykaczewski**
Propagation of ecological anomalies from the western to eastern North Pacific in a global earth system model (W6-6420)

13:40 **William T. Peterson, Hongsheng Bi, Cheryl A. Morgan and Edmundo Casillas**
The Pacific Decadal Oscillation and marine food webs in the northern California Current: Variations in source waters which feed the California Current may be the mechanism which links climate change with ecosystem response (W6-6385)

14:00 **Jay O. Peterson and William T. Peterson**
Evidence of climate change in the northern California Current ecosystem and its impact on the distribution and community composition of zooplankton (W6-6374)

14:20 **C. Tracy Shaw, Leah R. Feinberg and William T. Peterson**
Potential effects of climate change on the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* off Newport, OR, USA (W6-6047)

14:40 **Leah R. Feinberg and William T. Peterson**
Impacts of wintertime upwelling and primary production on euphausiid phenology and the productivity of upper trophic levels in the northern California Current (W6-6372)

15:00 **Motomitsu Takahashi, David M. Checkley, Jr., Richard D. Brodeur and William T. Peterson**
Responses in growth rate of larval northern anchovy and Pacific sardine to anomalous upwelling in 2005 in the northern California Current (W6-6421)

15:30 ***Coffee/Tea Break***

15:50 **Kazuaki Tadokoro and Yuji Okazaki**
Overview of the zooplankton from viewpoint of food for fish resources in the western North Pacific (W6-6418)

16:10 **Mikiko Kuriyama, Hiroya Sugisaki, Yuichi Hirota, Tadafumi Ichikawa, Hiroshi Itoh and Hiroshi Horikawa**
Long-term variation in copepod community structure in the Kuroshio area, off southern Japan

16:30 **Toru Kobari, Kazuaki Tadokoro, Hiroya Sugisaki and Hiroshi Ito**
Response of large grazing copepods to climate-oceanographic changes in the western subarctic Pacific Ocean (W6-6419)

16:50 Discussion

17:30 Workshop ends

# Abstracts

# Day 1 Plenary

**26 April, 8:55 (Plenary-6063)**

## The Earth's climate system: Variability and change

Kevin E. **Trenberth**

NCAR, P.O. Box 3000, Boulder, CO, 80307, USA. E-mail: trenbert@ucar.edu

An introduction will be given of the Earth's climate system. The roles of the atmosphere, ocean, cryosphere, and land will be described, and how energy (and heat) are moved around, stored, and released in different places and times to alter the regional and global climate. The role of humans will also be introduced with the finding that "global warming is unequivocal". A review will be given of the forcings of the climate system and their changes over time, and the response of the climate system as observed in variables including temperatures, precipitation, drought, hurricanes, sea ice, snow cover, ice sheets, and sea level, and our ability to model them. The main manifestations of change are through changes in extremes. The projections of future climate change will be introduced along with the challenges for making climate predictions.

**26 April, 9:25 (Plenary-6127)**

## Effects of climate change on marine ecosystems around Japan: Implications for sustainable fisheries

Akihiko **Yatsu**

Seikai National Fisheries Research Institute, Fisheries Research Agency, Taira-machi, Nagasaki, 851-2213, Japan
E-mail: yatsua@fra.affrc.go.jp

The Japanese Archipelago is surrounded by the Tsushima Current, Kuroshio and Oyashio, which are western boundary currents in the North Pacific Ocean. These currents influence climate, ecosystems and fisheries in the western North Pacific and its adjacent waters. This talk will present 1) observed and predicted physical and chemical changes in the North Pacific, 2) observed and potential effects of climate change on marine fishes and ecosystems particularly around Japan, and 3) their implications for sustainable fisheries, including adaptation by humans and marine species. In the high $CO_2$ world, it is generally considered that ocean temperature will rise, currents will spin-up, acidification will occur, sea ice will decrease, area of oligotrophic gyres will increase, and seasonality of biological productivity will change. Potential effects on marine fish species include distribution, productivity, ecological connectivity, biodiversity and phenology. For meaningful predictions of future of marine ecosystems, we need to understand mechanisms of population dynamics of major species in relation to the changes in ambient environment, including their rate of change and possible combined effects. Some examples of observed changes and outlook of selected marine ecosystems around Japan will be also presented. Adaptation by humans may include development of new technology and change in behaviors. For creation of adaptation ways for marine species, it is important to preserve their resiliency by reducing various stress posed by human activities. The ecosystem approach to fisheries can be useful for this purpose.

**26 April, 9:50 (Plenary-6029)**

## Cost of adapting global marine fisheries to climate change

Ussif Rashid **Sumaila**[1] and William L. Cheung[2]

[1] Fisheries Research Economic Unit, Fisheries Centre, University of British Columbia, Vancouver, BC, Canada, V6T 1E4
E-mail: r.sumaila@fisheries.ubc.ca
[2] School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK

We examine the cost of adapting fisheries to climate change by developing a number of scenarios of marine climate change impacts on fisheries. Climate change affects fisheries through changes in potential catch due to shifts in species' range and primary productivity available to the species; and direct impacts on species' productivity. Based on the spatial distribution of exploited fish species and available scientific information, we examine potential marine climate change impacts on catch through acidification of the oceans from higher $CO_2$ levels, loss of coral reefs from ocean warming, and changes in ocean biogeochemistry, such as oxygen levels. Three indicators of potential cost of adapting fisheries to climate change were identified: (i) the potential loss in gross revenues or landed values due to climate change; (ii) the capital that will be required as an endowment to replace the predicted loss in gross revenues; and (iii) the potential loss in household incomes from fisheries as a result of climate change. Based on the projected changes in catches, we determine the potential losses in (i-iii).

**26 April, 10:15 (Plenary-6413)**

## Climate change in perspective: The global drivers of change in fisheries

Edward H. **Allison**

Policy, Economics and Social Science, The WorldFish Center, Jalan Batu Maung, Bayan Lepas, Penang, 11960, Malaysia
E-mail: e.allison@cgiar.org

Human-induced global climate change is forecast to have increasing impacts on fishery systems. These changes are taking place within a context of demographic and economic changes which are in turn reflected in changing market systems for seafood products, the continuing rise of aquaculture as an alternative means to meet demand of fishery products, and evolving governance regimes to respond to signals of over-exploitation of wild fisheries. The interactions between these 'drivers of change' are not well known enough to inform the use of predictive systems models so that, in order to inform policy, we must consider them through exploration of scenarios. This talk aims to illustrate how climate-change impact research at various levels can be combined with analysis of the policy landscape to inform decision makers of the potential consequences of climate change for the future contribution of fisheries to economic and nutritional wellbeing.

Even within climate change, the main pathways of change are little known in terms of their relative magnitude. The emphasis of most marine fishery climate-impact studies is on the effects of ocean warming on the distribution and productivity of commercially-harvested fish species. For some fish production systems and their dependent people, however, the largest impacts may be felt through increased storm severity and frequency and the resulting damage to infrastructure, health and lives. For reef-dependent and shell-fish fisheries, coral bleaching and ocean acidification may be the pathways through which climate change has the greatest impact on production ecology and livelihoods. Broadening the scope of climate-change impacts research to include these pathways is both an urgent requirement and a scientific challenge.

Analyses of climate vulnerability are beginning to address this complexity by identifying areas, people and sub-sectors that are at greatest risk (or stand to benefit) from climate impact and other identified drivers of change. The growing practical application of systems-perspectives on fisheries (*e.g.* the ecosystem-based approach, resilience approach, value-chain analysis) offers a systematic framework with which to identify and address these issues.

In this talk, I will draw on recent work identifying key global drivers of change, conducting vulnerability analysis to climate change at a global level, and more localized or issue-driven studies that explore key pathways of impact in more detail. Examples will include a recent study on climate change impacts on trade competitiveness in small developing states, and an on-going study to inform options for aquaculture development in Vietnam, based on the analysis of the likely costs of various adaptation options. These cases illustrate how multi-scale coordinated research efforts can inform decision making for sustainability in the face of change, despite irreducible uncertainty.

# P1-D1 Oral Presentations



**26 April, 11:00 (P1-D1-6045)**

## Match/mismatch of fish population changes to climate events

James E. **Overland**[1], Andrew Bakun[2], Jürgen Alheit[3], James Hurrell[4], David Mackas[5] and Arthur Miller[6]

1 NOAA/ Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle WA, 98115, USA
E-mail: James.E.Overland@noaa.gov
2 Pew Institute for Ocean Science, RSMAS, University of Miami, 4600 Rickenbacker Causeway, Miami FL, 33149, USA
3 Institut für Ostseeforschung Warnemünde Biologie, Seestrasse 15, DE-18119, Warnemünde, Germany
4 NCAR / Climate and Global Dynamics Division, P.O. Box 3000, Boulder CO, 80307, USA
5 Fisheries and Oceans, Institute of Ocean Sciences, 9860 West Saanich Rd., Sidney, BC, V8L 4B2, Canada
6 Scripps Institution of Oceanography, SIO-UCSD 0224, La Jolla CA, 92093, USA

We suggest several types of ecosystem responses to climate change. Most climate variability is accounted for by the combination of intermittent 1-2 year duration events, *e.g.* the cumulative effect of monthly weather anomalies and the more organized ENSO, broad-band intrinsic variability operating at sub-decadal to longer timescales, and an emerging trend from greenhouse warming. While ocean processes such as heat storage and lags due to ocean circulation provide some multi-year memory, basic understanding of the mechanisms of decadal variability is lacking and forces the adoption of a long memory red noise conceptual model of low frequency climate variability. Climate events with rapid shifts and major departures from mean conditions will occur, but their explicit timing cannot be forecast. However, stochastic scenarios can be developed. The responses to climate shifts by biological systems are diverse because intervening processes introduce amplifications, time lags, feedbacks, and non-linearities, leading a variety of climate to ecosystem transfer functions. These can be expected to convert red noise of the physical system to redder (lower frequency) noise of the biological response, but can also convert climatic red noise to more abrupt and discontinuous biological shifts, transient climatic disturbance to a prolonged ecosystem recovery, and perhaps transient disturbance to sustained ecosystem regimes. All of these ecosystem response characteristics are likely to be active, leading to a mix of slow fluctuations, prolonged trends, and step-like changes in ecosystems and fish populations in response to climate change.

**26 April, 11:15 (P1-D1-6315)**

## Change in the North Pacific mixed layer depth and its impact on primary production in a warming world

Chan Joo **Jang** and Sinjae Yoo

Korea Ocean Research and Development Institute, 1270 Sa-dong, Ansan, Gyeonggi-do, 426-170, R Korea. E-mail: cjjang@kordi.re.kr

Projected changes in the ocean mixed layer depth (MLD) over the North Pacific under global warming are examined using climate models from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4). The MLDs consistently decrease up to 50% by the end of 21st century in the Kuroshio Extension (KE) in all the models examined. The MLD change in the western subploar region, on the other hand, varies significantly depending on models. Stratification measured by the buoyancy frequency intensifies especially within the main thermocline, supporting the idea that MLD under global warming will be decreased mainly due to intensified stratification. The KE front shifts northward in response to the wind stress curl shift, which provides an additional factor in understanding the spatial pattern of the MLD changes. These results suggest that changes in the wind stress and ocean circulation, in addition to the intensified surface stratification due to direct radiative warming, contribute significantly to MLD changes in a warming world. Given these changes in the upper mixed layer, we also make projections on their impacts on primary production. We estimate the change in primary production based on the change in the entrainment of nutrients by winter mixing at selected locations in the North Pacific.

**26 April, 11:30 (P1-D1-6105)**

## Integrating eco-physiology and plankton dynamics into projected global changes in marine biodiversity and maximum catch potential under climate change

William L. **Cheung**[1], John P. Dunne[2], Jorge Sarmiento[3] and Daniel Pauly[4]

1 School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK. E-mail: William.cheung@uea.ac.uk
2 Geophysical Fluid Dynamic Laboratory, NOAA, 201 Forrestal Rd., Princeton, NJ, 08540-6649, USA
3 Atmospheric and Oceanic Sciences Programme, Princeton University, 300 Forrestal Rd., Sayre Hall, Princeton, NJ, 08544, USA
4 Sea Around Us Project, Aquatic Ecosystems Research Laboratory, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada

Climate change is projected to strongly affect ocean conditions over the coming century and have large implications for the goods and services provided by marine ecosystems. Previous global scale studies of living marine resources have projected large potential change in marine biodiversity and redistribution of maximum catch potential across ocean basins by 2050 under the SRES A1B climate change scenario. However, these studies did not account for the effects of change in ocean biogeochemistry (*e.g.*, ocean acidification, oxygen content) and plankton dynamics (*e.g.*, planktonic community structure) which are recognized as important factors affecting the distribution and productivity of fish and shellfish. Here, we develop a new class of the dynamic bioclimate envelope model that allows us to include these factors in projecting future marine fish distributions and catch potential. Specifically, based on growth and metabolic theories, we model the effects of change in ocean acidity, oxygen content and other physical conditions on the eco-physiology of the studied species. We also account for changes in the trophic transfer from primary production to fish and shellfish as plankton community structure changes. This model then predicts changes in species' life history, population dynamics, distribution and their potential catch. We apply the model to a sample of exploited fish and shellfish using projections from the NOAA GFDL's Earth System Model. We examine the sensitivity of projected species distribution and catch potential to these biogeochemical and ecosystem factors.

**26 April, 11:45 (P1-D1-6089)**

## Possible change in distribution of seaweed, *Sargassum horneri*, in East Asia under A2 scenario of global warming and its impact on fishes

Teruhisa **Komatsu**[1], Masahiro Fukuda[1], Atsuko Mikami[1], Yutaka Kokubu[1], Shizuha Mizuno[1], Hideaki Tanoue[1] and Michio Kawamiya[2]

1 Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakanoku, Tokyo 164-8639, Japan
E-mail: komatsu@ori.u-tokyo.ac.jp
2 Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology, 3173-25 Showacho, Kanazawaku, Yokohama, 236-0001, Japan

Global warming effects on coastal marine ecosystems are already perceptible, especially in shallow water communities. The primary production of seaweed or seagrass beds in shallow waters is similar to that of tropical rain forests. Moreover, they constitute some highly valuable spawning, nursery and feeding grounds for numerous organisms in coastal waters. Geographical distributions of these plants greatly depend on water temperatures in summer and winter because they are very sensitive to maximum and minimum temperatures. As a result, it is expected that a water temperature increase will influence drastically the current distribution. To test this hypothesis, we referred to future water temperatures simulated by several organizations based on an A2 scenario of global warming. We processed these data to monthly mean water temperature at 1 degree in the Pacific Ocean. Using simulated surface water temperatures in February and August in 2050 and 2099, we examined changes in the spatial distribution of a specific seaweed species: *Sargassum horneri*. This species was selected due to ecological importance: formation of large seaweed beds and wide thermal tolerance. The southern limit of *S. horneri* distribution is expected to keep moving northward such that it may broadly disappear from Honshu Island, the Chinese coast, and Korean Peninsula by 2099. Since *S. horneri* forms drifting seaweeds in East China Sea and these floating rafts constitute a key nursery ground for yellowtail and jack mackerel spawning there, *S. horneri* disappearance is expected to damage significantly not only fishes related to the coastal waters but also pelagic ones.

**26 April, 12:00 (P1-D1-6313)**

## Fisheries and ecosystems in a changing climate: A case study on the Tasmanian east coast lobster fishery

Stewart **Frusher**[1], Gretta Pecl[1], Caleb Gardner[1], Marcus Haward[2], Alistair J. Hobday[3], Sarah Jennings[4], Melissa Nursey-Bray[5], André E. Punt[6], Hilary Revill[7] and Ingrid van Putten[3]

1 Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Private Bag 49, Hobart, Tasmania, 7001, Australia
E-mail: stewart.frusher@utas.edu.au
2 School of Government, University of Tasmania, Private Bag 5, Hobart, Tasmania, 7001, Australia
3 CSIRO Marine and Atmospheric Research, Castray Esplanade, Hobart, Tasmania, 7001, Australia
4 School of Economics and Finance, University of Tasmania, Private Bag 5, Hobart, Tasmania, 7001, Australia
5 National Centre for Marine Conservation and Resource Sustainability, Australian Maritime College, Locked Bag 1370, Launceston, Tasmania, 7248, Australia
6 School of Aquatic and Fishery Sciences, University of Washington, Box 305520, Seattle, WA, 98195, USA
7 Wild Fisheries Management Branch, Department of Primary Industries, Parks, Water and Environment, P.O. Box 44, Hobart, Tasmania, 7001, Australia

Climate change adaptation research requires inter-disciplinary studies to underpin the policy required to manage both biophysical and human systems. In marine domains, climate induced changes in water temperature and ocean currents can change the productivity of resources which in turn alters the spatio-temporal distribution of users (*e.g.* fishers) with social and economic flow-on effects to communities. This presentation is based on results from a recently completed Australian National Coastal Vulnerability Case Study on the rock lobster fishery off Eastern Tasmania in south-eastern Australia. This fishery, located in a region predicted to be the fastest warming in the southern hemisphere, provides early warning signals for consideration in fisheries globally. Direct impacts relate to forecast changes in growth and recruitment whereas indirect impacts, already in full swing, affect ecosystem services through major changes in ecosystem resilience. Predicted effort re-distribution of the commercial fleet, recreational fishing activity and maintenance of lobster biomass to counter-act an invasive poleward moving urchin are all linked through a common climate impact. Climate change adaption can be viewed by managers and industry as a future decision because incremental changes appear small. This study demonstrates the need to consider climate related impacts in current fisheries management.

**26 April, 12:15 (P1-D1-6036)**

## The oscillating control hypothesis: Reassessment in view of new information from the eastern Bering Sea

George L. **Hunt**, Jr.[1], Lisa B. Eisner[2], Edward W. Farley[2], Jamal H. Moss[2], Jeffrey M. Napp[3] and Phyllis J. Stabeno[4]

1 School of Aquatic and Fishery Sciences, University of Washington, P.O. Box 355020, Seattle, WA, 98195, USA
E-mail: geohunt@uw.edu
2 NOAA/NMFS/AFSC, Auke Bay Laboratories, Ted Stevens Marine Research Institute, 17109 Point Lena Loop Rd., Juneau, AK, 99801, USA
3 NOAA Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115-6349, USA
4 NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA, 98115-6349, USA

In the southeastern Bering Sea, recent years have provided opportunities to examine differences in ecosystem responses to years with early ice retreat ("warm years") and years with late ice retreat ("cold years"). In springs with an early ice retreat and a bloom in warm water (>3°C), small neritic copepods, which are appropriate food for very young pollock, support early juvenile survival, but these small copepods are insufficient prey to allow older age-0 pollock to lay down lipids in summer and fall. Thus in years with early ice retreat, there are high numbers of age-0 pollock in summer with low energy reserves, and these fish are unlikely to survive their first winter. Additionally, in warm years with reduced availability of the large shelf copepod, *Calanus marshallae,* and shelf euphausiids, predation on small pollock by larger pollock increases, further eroding year-class strength. In years with late ice retreat, *C. marshallae* is favored, and although there may be fewer surviving age-0 pollock at the end of spring, by summer, they have greater lipid reserves and a higher probability of surviving their first winter. Further, in cold years, both shelf euphausiids and *C. marshallae* are abundant in summer, and are targeted by larger pollock and salmon, thereby reducing predation on age-0 pollock. Thus, warm years with early ice retreat are unlikely to yield strong year-classes of pollock, whereas years with late ice retreat may yield strong year-classes if the biomass of larger pollock is not so great as to cause heavy losses through cannibalism.

**26 April, 12:30 (P1-D1-6364)**

## The response of fish populations to climate change forecasted by integrating a sequence of models over different life stages: Anchovy in the Bay of Biscay

Martin Huret, Pierre **Petitgas** and Caroline Struski

IFREMER, rue de l'Île d'Yeu, BP 20115, 44311 cdx 3, Nantes, France. Email: pierre.petitgas@ifremer.fr

Fish populations show complex life cycles with different life stages exploiting a variety of habitats. Larval dispersal and fish movements spatially connect the habitats of the different life stages. Each life stage has particular habitat requirements and the availability of these may change in space and time with climate change. The response to climate change may be conflicting in the different life stages. Therefore, to predict the response of populations to climate change, one needs to integrate over the entire life cycle. For that, different models of anchovy life stages were used sequentially to evaluate the population potential response to climate change. We used the outputs of a coupled hydro-biogeochemical model to access to the environmental forcing fields. A bioenergetic model resolved individual fish growth and reproduction and determined the spawning time, duration and total fecundity. A statistical habitat model determined the spawning locations depending on population abundance and length structure. These models provided the initial conditions for running a larval individual-based model to determine the drift and the survival of the larvae. Climate change scenarios were constructed by deviating major forcing parameters of the hydro-biogeochemical model (wind, air temperature, short wave radiation, river runoff) from the current situation. These results of the scenarios were contrasted with the hindcast simulated series. In scenarios with higher temperature, the spawning season was earlier, which impacted the larval drift and therefore a potential shift of the population to the north, where habitats had become suitable.

**26 April, 12:45 (P1-D1-6387)**

## State-space analysis of ocean and atmospheric data for use in forecasting ecological impacts of climate change

Roy **Mendelssohn** (presented by Frank Shwing)

NOAA-Fisheries, Southwest Fisheries Science Center, Pacific Fisheries Environmental Laboratory, Pacific Grove, CA, 93950, USA
E-mail: roy.mendelssohn@noaa.gov

An important consideration in examining climate effects on marine resources is to properly separate long-term changes in the mean from changes in the seasonality and from changes due to stationary dynamics, to properly identify change points, if any, and to develop indices that can reflect these properties. While stationary dynamics are important in year-to-year variability, they do not reflect changing dynamics due to climate change. State-space decompositions combined with subspace identification methods provide the tools to examine these questions. I will review over a decade of results using these methods, examining surface and subsurface temperatures, pressure centers and major climate indices. While the emphasis will be on the Pacific Ocean, and comparing changes in the different Large Marine Ecosystems (LMEs) of the Pacific, the results will be put into a global context. These results present a different picture of the dynamics of the Pacific Ocean, and perhaps better explain at least part of the variability seen in living marine resources in the region.

**26 April, 14:30 (P1-D1-6292)**

## Life cycle ecophysiology of small pelagic fish: Environmental thresholds and climate-driven changes in populations

Myron A. **Peck**[1], Patricia Reglero[2], Motomitsu Takahashi[3] and Ignacio A. Catalán[4]

[1] Institute of Hydrobiology and Fisheries Science, University of Hamburg, Olbersweg 24, D-Hamburg, 22767, Germany
E-mail: myron.peck@uni-hamburg.de
[2] Instituto Español de Oceanografía, Centre Oceanogràphic de les Balears, Moll de Ponent s/n, 07015, Palma, Spain
[3] Seikai National Fisheries Research Institute, 1551-8 Taira-machi, Nagasaki-shi, Nagasaki, 851-2213, Japan
[4] Instituto Mediterraneo de Estudios Avanzados (IMEDEA, UIB/CSIC), c/Miquel Marques 21, 07190, Esporles, Illes Balears, Spain

Due to their relatively short life spans, high rates of growth and reproduction and trophic position, small pelagic fish are excellent bio-indicators of climate variability and change. In an attempt to identify stage-specific, ecophysiological constraints underpinning climate-driven changes in distribution and abundance, we reviewed available information on the impacts of key environmental factors on the vital rates of five small pelagic (Clupeiform) fish with emphasis on five species inhabiting Northwest Pacific or Northeast Atlantic and Mediterranean waters. The review was organized using a matrix of environmental (extrinsic) factors that included both abiotic (*e.g.*, temperature, salinity, light) and biotic (prey abundance/concentration and preferences) factors. Vital rates included: 1) adult spawning, 2) survival and development of endogenously feeding life stages (eggs, yolk sac larvae), and 3) feeding and growth of young-of-the-year (YOY) fish (larvae, post-larvae and juveniles). Gaps in basic knowledge were identified, particularly regarding growth bioenergetics of later life stages primarily due to challenges of captive rearing. Interspecific differences in the impact of temperature on vital rates partly explain changes in distribution and/or productivity. Prey availability during the late larval and early juvenile period appears to be one of the most important factors responsible for density-dependent fluctuations observed in Northwest Pacific and Northeast Atlantic populations. We 1) discuss processes causing observed changes in stocks, 2) summarize existing research gaps for each life stage, and 3) recommend future ecophysiological studies most needed to develop robust, physiologically-based, biophysical models projecting climate impacts on the distribution and productivity of small pelagic fish species.

**26 April, 14:45 (P1-D1-6141)**

## Performance of multiple approaches in modelling small pelagic fish distribution: Predictive ability in the light of climate change

Dawit **Yemane**, Nandipha M. Twatwa and Janet C. Coetzee

Marine and Coastal Management, Department of Environmental Affairs, Rogge Bay 8012, Private Bag X2, Cape Town, South Africa
E-mail: dawityemane@gmail.com; DYemane@deat.gov.za

Multiple bioclimatic models have been used to model distribution patterns and abundance of several biota. These models vary in their complexity and assumptions they require of the data. A large number come from terrestrial environment. In the marine environment the use of such approach are generally limited to a single method and comprehensive analysis of the performance of multiple bioclimatic models are scant. This study attempts to address model selection issue using South African small pelagic fish species as a case study. This study was conducted based on data on the three major small pelagic fish species (Anchovy *Engraulis capensis*, Sardine *Sardinops sagx*, and Redeye *Etrumeus whiteheadi*). For the purpose of this study we selected six of the most commonly used bioclimatic modelling tools (GAM, GLM, MARS, CART, BRT, and ANN). The result shows some similarity in predictive performance between some of the models whereas differences between others. This modelling is expected to contribute towards the knowledge in the selection among bioclimatic models in predicting future changes in the distribution and abundance of important fish species.

**26 April, 15:00 (P1-D1-6308)**

## Climate change and small pelagic fish: A review and recommendations

Pierre Fréon[1], David M. **Checkley**, Jr.[2] and Francisco E. Werner[3]

[1] Unité EME R212, CRHMT, Centre de Recherche Halieutique Méditerranéenne et Tropicale, IRD - IFREMER and Université Montpellier II, Avenue Jean Monnet, BP 171, 34203 Sète Cedex, France. E-mail: pfreon@ird.fr
[2] 2220 Sverdrup Hall, Scripps Institution of Oceanography, 8615 Kennel Way, La Jolla, CA, 92037, USA
[3] Institute of Marine and Coastal Sciences, 71 Dudley Rd., Rutgers University, New Brunswick, NJ, 08901, USA

The Small Pelagic Fish and Climate Change (SPACC) program facilitated research on the dynamics of populations of small pelagic fish (SPF). These populations exhibit large variations in size, extent, and production on the scale of decades. Collectively, SPF can occupy a central but questioned role in the food web where they occur, often described as a wasp-waist ecosystem, with humans increasingly playing an integral part of those ecosystems. Variability of SPF populations is believed due primarily to variations in climate and fishing, but mechanisms of these relations remain unknown in most cases. It is also uncertain whether these ecosystems alternate between states, and whether inherent variability may limit our ability to predict future states. Here, we review scenarios of climate change and physical oceanography. Three predicted avenues of ecological change are discussed: changes in productivity and composition of lower trophic levels; distributional changes of marine organisms; and changes in circulation and their effects on recruitment. Research gaps are identified with attention to current limitations of available data and models. SPACC has benefited from the global comparison of populations and regions with SPF. Although each stock and region is unique, common properties exist. Among these are the recognition of the influence of varying climate on populations, consistency within and differences between populations, the pivotal role in wasp-waist ecosystems, the global nature of interactions involving SPF, and the certainty of future change in climate and demand for SPF. To facilitate future research on climate change and SPF, we recommend an international program like SPACC.

**26 April, 15:15 (P1-D1-6349)**

## Modeling secondary production in the Norwegian Sea with a fully coupled physical-primary-secondary production model system

Solfrid Sætre **Hjøllo**, Geir Huse, Morten D. Skogen and Einar Svendsen

Institute of Marine Research, P.O. Box 1870, Nordnes, Bergen, 5817, Norway. E-mail: Solfrid.Hjollo@imr.no

The copepod *Calanus finmarchicus* is the dominant species of the mesoplankton in the Norwegian Sea, and constitutes an important link between the phytoplankton to the higher trophic levels in the Norwegian Sea food chain. An individual-based model for *C. finmarchicus*, based on superindividuals and evolving traits for behavior, stages, *etc.*, are two-way coupled to a physical-biological model system. One year of modeled *C. finmarchicus* spatial distribution, production and biomass are compared to point-wise and integrated observations, and found to represent these satisfactory. Sensitivity tests of model setup (*i.e.* no of superindividuals, initial values of traits for behavior and food preferences) show that the modeling system is robust and provides a valuable tool for studies of ecosystem responses to causative forces such as fish predation or climate change. From a longer simulation, interannaul variability and regional differences in biomass and production are studied.

**26 April, 15:30 (P1-D1-6266)**

## Potential impact of climate change on Pacific saury

Shin-ichi **Ito**[1], Takeshi Okunishi[2], Michio J. Kishi[3,4] and Muyin Wang[5]

1 Tohoku National Fisheries Research Institute, FRA, 3-27-5 Shinhama-cho, Shiogama, Miyagi, 985-0001, Japan
E-mail: goito@affrc.go.jp
2 National Research Institute of Fisheries Science, FRA, Kanazawa-Ku, Yokohama, Kanagawa, 236-8648, Japan
3 Faculty of Fisheries Sciences, Hokkaido University, Sapporo, Hokkaido, 060-0813, Japan
4 Frontier Research Center for Global Change, JAMSEC, Yokohama, Kanazawa, 236-0001, Japan
5 Joint Institute for the Study of Atmosphere and Ocean, University of Washington, Seattle, WA, 98115, USA

An ecosystem based bioenergetics model NEMURO.FISH (North Pacific Ecosystem Model for Understanding Regional Oceanography). For Including Saury and Herring was developed and successfully reproduced realistic growth of Pacific saruy with parameters mainly determined based on field observations. The model is composed of three ocean domain boxes and saury is assumed to migrate between those boxes. The model is very simple but it also reasonably captured the growth difference between autumn, winter, and spring-spawned cohorts. This model was used to investigate responses of Pacific saury to global warming using the sea surface temperature (SST) of current climatology and a global warming condition generated by MIROC3.2 coupled atmospheric-ocean model output with A2 scenario. The saury showed decrease in both wet weight and body length under global warming because of less prey plankton density. The migration pattern was modified by increased SST and reduced size of saury. Higher SST in the mixed water region under global warming prevented southern migration of saury in the first winter and delayed it in the second winter. As a result, the egg production was enhanced by higher availability of prey zooplankton in the mixed water region. The result may depend highly on the magnitude of SST increase. We will compare the results using several climate model outputs at the presentation.

**26 April, 15:45 (P1-D1-6106)**

## Development of a climate-to-fish-to-fishers model: Proof-of-principle using long-term population dynamics of anchovies and sardines in the California Current

Kenneth A. **Rose**[1], Enrique N. Curchitser[2], Kate Hedström[3], Jerome Fiechter[4], Miguel Bernal[2], Shin-ichi Ito[5], Salvador Lluch-Cota[6], Bernard A. Megrey[7], Christopher A. Edwards[4], David M. Checkley, Jr.[8], Alec MacCall[9], Tony Koslow[10], Sam McClatchie[9], Kenneth L. Denman[11] and Francisco E. Werner[2]

1 Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA, 70803, USA
Email: karose@lsu.edu
2 Institute of Marine and Coastal Sciences, 71 Dudley Rd., Rutgers University, New Brunswick, NJ, 08901, USA
3 Arctic Region Supercomputing Center, 909 Koyukuk Dr., Suite 105, Fairbanks, AK, 99775, USA
4 Ocean Sciences Department, University of California, Santa Cruz, CA, 95064, USA
5 Tohoku National Fisheries Research Institute, FRA, 3-27-5 Shinhama-cho Shiogama-city, Miyagi, 985-0001, Japan
6 CIBNOR, Mar Bermejo # 195 Col. Playa Palo de Santa Rita, La Paz, B.C.S., 23090, Mexico
7 Alaska Fisheries Science Center-NOAA, 7600 Sand Point Way NE, Seattle, WA, 98115, USA
8 Scripps Institute of Oceanography, UC San Diego, 9500 Gilman Dr., La Jolla, CA, 92093, USA
9 NOAA Fisheries Service, Southwest Fisheries Science Center, 8604 La Jolla Shores Dr., La Jolla, CA, 92037-1508, USA
10 Scripps Institute of Oceanography, CalCOFI, 9500 Gilman Dr., La Jolla, CA, 92093, USA
11 Canadian Centre for Climate Modelling and Analysis; DFO, Institute of Ocean Sciences, 9860 West Saanich Rd., Sidney, BC, V8L 4B2, Canada

An ecosystem approach to understanding large-scale patterns in exploited fisheries systems caused by both climate change and human activity increasingly relies on the use of numerical models. In the past, physical, lower, and higher trophic level models were developed, tested, and implemented independently of each other. Recently, advances in physics and biology have made possible end-to-end (climate-to-fish-to-fishers) ecosystem models, including humans as a dynamical component. We present our progress to date on the development of an end-to-end modeling framework within the widely-used ROMS (Regional Ocean Modeling System) circulation model. The NEMURO Nutrient-Phytoplankton-Zooplankton (NPZ) submodel provides the lower trophic level dynamics, and a multi-species, individual-based, full life cycle submodel simulates fish population and community dynamics, including fishing fleets as one of the predator species. We describe our preliminary version of the modeling framework, which focuses on anchovies and sardines in the California Current system. Using a relatively coarse 30-km resolution ROMS model, we demonstrate how the various submodels can be solved simultaneously for a multi-decadal historical simulation (1958-2006) and present preliminary model results on key physical features (*e.g.*, interannual variation in upwelling), lower trophic dynamics (*e.g.*, zooplankton community composition

and productivity), and anchovy and sardine growth, spawning, mortality, and movement patterns. While many biological and computational challenges remain, we believe a dedicated modeling effort, developed in concert with retrospective analyses and existing field programs, will lead to management-ready end-to-end forecasting tools in the future.

**26 April, 16:20 (P1-D1-6052), Invited**

## Uncertainties about climatic change and Pacific salmon: Risk assessment, risk communication, and risk management

Randall M. **Peterman**

School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC, V5A 1S6, Canada. E-mail: peterman@sfu.ca

Because of the numerous uncertainties about forecasting effects of climatic change on Pacific salmon populations, the methods of risk assessment, risk communication, and risk management are useful. I will discuss these fields in the context of five major sources of uncertainty: natural variability, observation error, structural complexity, outcome uncertainty (*i.e.*, implementation uncertainty), and inadequate communication among scientists, decision makers, and stakeholders. Natural variability in both salmon populations and their environmental drivers occurs at both short and long periods and at various spatial scales. Efforts to use outputs from climate models should therefore link environmental indicators to salmon variables at appropriate temporal and spatial scales. However, past data contain observation errors, making it difficult to discern true underlying relationships. Nevertheless, this problem can be at least partially dealt with by (1) using state-space or errors-in-variables models that explicitly estimate parameters for each of natural variation and observation error, and (2) fitting hierarchical models to reflect spatial covariation among nearby populations arising from shared environmental drivers. In the last decade, structural uncertainty about relationships among components of aquatic systems has been recognized as a larger source of uncertainty than natural variation and observation error. A popular method of dealing with structural uncertainty is to run stochastic simulation models across hundreds of scenarios (*i.e.*, assumed relationships) using closed-loop simulations (management strategy evaluations). Finally, this paper will describe some methods for dealing with communication about uncertainty and risk among scientists, decision makers, and stakeholders, a topic that has had too little research.

**26 April, 16:45 (P1-D1-6301)**

## Biological ensemble modelling of climate impacts – Improving fisheries science and management by accounting for uncertainty

Anna Gardmark[1], Stefan Neuenfeldt[2], Martin **Lindegren**[2], Thorsten Blenckner[3], Eero Aro[4], Outi Heikinheimo[4], Bärbel Müller-Karulis[5], Susa Niiranen[3], Maciej Tomczak[2], Anieke van Leeuwen[6], Anders Wikström[7] and Christian Möllmann[8]

1 Institute of Coastal Research, Swedish Board of Fisheries, P.O. Box 109, Öregrund, SE-742 41, Sweden
E-mail: anna.gardmark@fiskeriverket.se
2 National Institute of Aquatic Resources, Dept. of Marine Fisheries, Charlottenlund Slot, 2920 Charlottenlund, Denmark
3 Baltic Nest Institute, Stockholm Resilience Center, Stockholm University, Stockholm, SE-106 91, Sweden
4 Finnish Game and Fisheries Research Institute P.O. Box 2, Viikinkaari 4, Helsinki, FIN-00791, Finland
5 Latvian Institute of Aquatic Ecology, 8 Daugavgrivas, Riga, LV-1048, Latvia
6 Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Kruislaan 320, Amsterdam, 1098 SM, The Netherlands
7 Department of Theoretical Ecology, Ecology Bldg., Lund University, Lund, SE-22362, Sweden
8 Institute of Hydrobiology and Fisheries Science, University of Hamburg, Olbersweg 24, Hamburg, D-2276, Germany

Predicting fish stock responses to climate change fundamentally relies on mathematical models of population dynamics. The ecosystem-based approach to fisheries management further requires that management accounts for interactions among species and other ecosystem processes. Thus, diversity and complexity of models used for predicting fish stock responses to management have increased. Yet, the structural uncertainty associated with alternative models is rarely accounted for. Here we present the biological ensemble modelling approach (BEMA) to deal with such structural uncertainty. We further illustrate how the technique can be used to disentangle structural uncertainty from the statistical uncertainty of climate predictions. Four single-species models, four multi-species models and one food-web model were used to predict the response of Eastern Baltic cod (*Gadus morhua callarias*) to five alternative fisheries management scenarios and two climate change scenarios, assuming

no climate change or a warmer and less saline future Baltic Sea. Although predictions differed also qualitatively between the models, the BEMA provided a means to (i) present the full set of projected stock responses, (ii) assess whether these imply different conclusions on management, and (iii) draw general conclusions valid across all models used. Based on this example we will discuss benefits and limitations of the BEMA in furthering both fisheries management and fisheries science.

**26 April, 17:00 (P1-D1-6214)**

## Future recruitment of Bering Sea walleye pollock. Part I: Retrospective patterns and uncertainty

Franz J. **Mueter**[1], Nicholas A. Bond[2], Anne B. Hollowed[3], Carol Ladd[2] and Enrique N. Curchitser[4]

1 School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, 99801, USA. E-mail: fmueter@alaska.edu
2 Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, WA, 98195, USA
3 National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115, USA
4 Institute of Marine and Coastal Science, Rutgers University, New Brunswick, NJ, 08901, USA

One of the key uncertainties in predicting the response of fish populations to future climate variability is uncertainty about future reproductive success. We illustrate a possible approach to providing plausible recruitment projections and their associated uncertainty under different climate scenarios using walleye pollock in the eastern Bering Sea as an example. First, we build on hypothesized mechanisms controlling pollock recruitment in the eastern Bering Sea to derive statistical relationships linking regional oceanographic conditions to pollock recruitment. Second, we use a statistical downscaling approach to forecast these regional oceanographic conditions from IPCC model simulations. Third, we use statistical models developed in the first step to forecast time series of future recruitment of walleye pollock. Full uncertainty in the forecasted time series will be quantified by combining prediction uncertainties from the statistical models with uncertainty in the IPCC model simulations. This talk will focus on the first step to better understand and quantify the effects of past climate variability on observed recruitment. In particular, we will re-examine the role of the timing of the spring bloom, the strength of summer stratification, and cannibalism in determining pollock recruitment. Because these oceanographic variables have only been measured in recent years we compare three approaches to obtaining hindcasts of bloom timing and stratification for predicting recruitment using (1) statistical relationships between climate variables and oceanographic variables, (2) output from a 1-D mixing model, and (3) output from a regional ocean circulation model. Results from this part of the study will be used in a companion paper by Bond *et al.* to forecast pollock recruitment.

**26 April, 17:15 (P1-D1-6068)**

## Future recruitment of Bering Sea walleye pollock. Part II: Ranges in key environmental parameters from global climate model forecasts

Nicholas A. **Bond**[1], Franz J. Mueter[2], Anne B. Hollowed[3], Carol Ladd[3] and Muyin Wang[1]

1 Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, WA, 98195, USA
E-mail: nicholas.bond@noaa.gov
2 School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, 99801, USA.
3 National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA, 98115, USA

The paper of Mueter *et al.* for this session uses retrospective data to quantify how the recruitment of walleye pollock in the Bering Sea relates to environmental parameters. Those relationships are used here to make projections of pollock recruitment through the first half of the 21st century. The key environmental parameters for Bering Sea pollock, including the timing of the spring bloom and the magnitude of the water column stratification in summer, are derived from large-scale elements of the climate system using empirical methods. For the 21st century projections, the climate-scale forcing is specified with output from the global model simulations carried out for the 4th Assessment Report (AR4) of the Intergovernmental Panel of Climate Change (IPCC). Our procedure has three sources of errors and uncertainties: (1) in the relationships between recruitment and environmental indices, (2) in the linkages between these indices and the elements of the climate forcing that are directly predicted by IPCC-class models, and (3) in the range of the plausible outcomes for the climate system itself. The magnitudes

of each of these sources are compared in terms of their contribution to the overall error in estimating recruitment. Our study it designed to complement the vertically-integrated modeling effort being carried out under the auspices of the BEST/BSIERP program.

**26 April, 17:30 (P1-D1-6183)**

## Numerical simulations of spatio-temporal distribution of juvenile walleye pollock around Hidaka Bay

Hiroshi **Yoshinari**, Tomonori Azumaya, Tetsuichiro Funamoto, Akira Kusaka, Orio Yamamura and Akira Nishimura

Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsurakoi, Kushiro, Hokkaido, 085-0802, Japan
E-mail: hyy@affrc.go.jp

Hidaka Bay, situated along the southwestern coast of Hokkaido, is an important spawning ground of the Japan Pacific population (JPP) of walleye pollock. Previous studies have revealed that: 1) juvenile pollock are concentrated in Funka Bay, western side of Hidaka Bay, in April and 2) their distribution are apparently related to warmer water (*i.e.*, $T_{10} > 3.5$°C). To elucidate the mechanism of intake and maintenance of juvenile pollock in Funka Bay, we performed a numerical simulation. In the simulation, particles were initially distributed uniformly in the surface layer of Funka Bay, then a time-inverse integration from April 26 to January 25 was executed to determine the sites where the juveniles originated from using ROMS (Regional Ocean Model System) climatological run. The particles reached the south side of the entrance of Funka Bay, then turned around the northward and flowed eastward along the coastline of Hidaka Bay, which is consistent with the empirically known spawning ground. Surprisingly, considerable fractions of particles (30 % of the total) were transported beyond Cape Erimo by January 25, the presumed mean spawning day, implying some possibility that the spawning area of the JPP extends farther eastward than has been supposed. In the presentation, the effects of the wind over Hidaka Bay on the distribution of juvenile walleye pollock in Funka Bay will also be mentioned.

**26 April, 17:45 (P1-D1-6396)**

## Modeling recruitment responses of striped marlin (*Tetrapturus audax*) and swordfish (*Xiphias gladius*) to environmental variability in the North Pacific

Jon **Brodziak**, Kevin Piner and Dean Courtney

NOAA Fisheries, Pacific Islands Fisheries Science Center, 2570 Dole St., Honolulu, HI, 96822, USA. E-mail: Jon.Brodziak@NOAA.gov

We investigated alternative models to predict recruitment strength of North Pacific striped marlin and swordfish. Our goal was to identify key environmental variables needed to model recruitment responses. This represented one step in a general framework for modeling fish stock responses to future climate change. Estimates of recruitment and spawning biomass were gathered from recent age-structured assessments using the Stock Synthesis model. Indices of early life history survival ratios for striped marlin and swordfish, measured by the ratio of recruitment to spawning biomass (RS), were compared with two indices of climate variability, the Pacific Decadal Oscillation (PDO) and the Southern Oscillation Index (SOI), to investigate their potential influence on recruitment success. Regression models to predict log-transformed RS values from PDO and SOI indices during spawning season were fit. AIC values indicated that the PDO was the best predictor of RS for striped marlin while for swordfish, SOI was the best predictor. For comparison, separate regression analyses were conducted using RS values adjusted for stock-recruitment steepness. Both results were used to parameterize alternative models of recruitment strength for making stock projections under current fishery conditions with model selection uncertainty. Overall, striped marlin appeared less resilient than swordfish to fishing pressure accounting for environmental forcing.

**26 April, 18:00 (P1-D1-6215)**

## Integrating data, fieldwork, and models into an ecosystem-level forecasting synthesis: The modeling challenge of the Bering Ecosystem Study/Bering Sea Integrated Research Program (BEST-BSIERP)

Kerim Aydin[1], Nicholas A. Bond[2], Enrique N. Curchitser[3], Georgina A. Gibson[4], Kate Hedström[4], Albert J. Hermann[5] and Ivonne **Ortiz**[2]

1 Alaska Fisheries Science Center, NMFS, NOAA, 7600 Sand Point Way NE, Seattle, WA, 98115-0070, USA
E-mail: Kerim.Aydin@noaa.gov
2 Joint Institute for the Study of Atmosphere and Ocean (JISAO), University of Washington, 7600 Sand Point Way NE, NOAA/PMEL, Seattle, WA, 98195-4925, USA. E-mail: ivonne@u.washington.edu
3 Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ, 08901, USA
4 International Arctic Research Center, University of Alaska Fairbanks, 930 Koyukuk Dr., Fairbanks, AK, 99775-7340, USA
5 Joint Institute for the Study of Atmosphere and Ocean (JISAO), University of Washington, 7600 Sand Point Way NE, NOAA/PMEL, Seattle, WA, 98115, USA

The Bering Ecosystem Study/Bering Sea Integrated Research Program (BEST-BSIERP, http://bsierp.nprb.org/index.htm) is a five-year program of over 90 principal investigators, jointly sponsored by the National Science Foundation (NSF) and the North Pacific Research Board (NPRB) to provide a synthesis of key hypotheses that govern the effects of climate on the Bering Sea ecosystem, and provide a set of tools for forecasting long-term production and distribution of marine resources (*e.g.* plankton, fish, birds, and mammals). BSIERP is unique in its approach to integrating data, fieldwork with modeling efforts throughout the project. First, scoping models (*e.g.* food web, bioenergetics, and nutrient-phytoplankton-zooplankton models) guided project design, for example by investigating the link between ice and plankton or between fish growth and prey variation. Second, the models are being developed concurrently with (rather than after) the field program, to guide sampling priorities and help interpret observations. Third, model components are modular, so that "alternate modules" (*e.g.* behavioral models, or models with differing resolutions ranging from a complex vertically-integrated end-to-end model with 10km resolution to broad correlative models) may be substituted to determine the most appropriate toolbox for forecasting. Here, we show results of model predictions related to recent, present, and immediately future field conditions combined with data assimilation and validation. We focus on predictability: using the wide range of resources at our disposal today, what's possible, what's missing, what predictions are robust, and what surprises we might have in store, as we move to attempting to forecast longer-term (20-50 year) outlooks for marine ecosystems.

**26 April, 18:15 (P1-D1-6275)**

## Potential climate change impacts on fish production from 20 large marine ecosystems around the world

Julia L. **Blanchard**[1], Nicholas K. Dulvy[2], Robert Holmes[3], Manuel Barange[3] and Simon Jennings[4]

1 Division of Biology, Imperial College London, Silwood Park Campus, Buckhurst Rd., Ascot, SL5 7PY, UK
E-mail: j.blanchard@imperial.ac.uk
2 Biological Sciences, 8888 University Dr., Simon Fraser University, Burnaby, BC, V5A 1S6, Canada
3 Plymouth Marine Laboratory Prospect Place Plymouth, PL1 3DH, UK
4 Centre for Environment Fisheries and Aquaculture Sciences, Pakefield Rd., Lowestoft, NR33 0HT, UK

In the absence of detailed knowledge on how fish species will respond to climate change, simple macroecological approaches can be usefully employed to investigate the potential impacts on production of marine ecosystems across a body size range typically encompassing mesozooplankton and fish larvae up to the largest predatory fishes. Statistical models can be used to establish relationships between observed primary production and fishery yields. Simple theory based on the transfer of energy from smaller to larger organisms and temperature dependence on metabolic rates can be used to predict the static abundance-body size distribution from primary productivity and temperature. Dynamic size spectrum models allow for time-dependent processes to be taken into account and testing effects of different fishing scenarios on the size spectrum.

Using a coupled physical-biogeochemical model, climate-mediated changes in primary productivity and temperature were modelled for 20 large-marine ecosystems around the world under past and far-future climate change scenarios. This information was used to force a static size-based scaling model and a dynamic size spectrum model to estimate the potential abundance-size distributions of marine predators, across size ranges that are typically dominated by fish and squid. The dynamic size spectrum model is then used to investigate the effects of different size-selective fishing strategies on potential yield of the overall system. We compare potential production estimates from both size-based models in the absence of exploitation to present day observed catches of small pelagic, demersal and large pelagic fishes and discuss the potential implications for fisheries in the future.

# P1-D1 Posters



### P1-D1-5977

## The ramification of climate change on aquaculture production in Cameroon

Nkemasong Samuel **Acha** and Thomas Tazoche **Njang**

Department of Fisheries, Action Centre for Rural Community Development (ACERCD-Cameroon), P.O. Box 144, Buea, South West Region, 237, R of Cameroon. E-mail: acercd98@yahoo.com

The world's dependence on the capture fisheries and aquaculture sector is threatened not only by inadequate management of these aquatic resources but also on factors external to the sector such as climatic change. Fishers and fish farmers in coastal and inland areas are particularly vulnerable to the direct and indirect impacts of climate change. Since the largest proportion of world aquaculture production is concentrated in tropical and sub-tropical climatic regions, and geographically in the sub-Saharan Africa, impacts from climate change are likely to have greater consequences there, with direct impacts on global food fish supply. However, it is predicted that global warming and the consequent increase in water temperature could impact significantly and negatively on aquaculture in temperate climatic zones, because such increases could exceed the optimal temperature range of cultured organisms, as opposed to potential positive impacts through enhanced growth and production in tropical and sub-tropical zones. The paper will analyze the negative impact of climate change on the aquaculture production in Cameroon, such as the reduction of ecosystem activities. It will dwell in detail on the various climatic changes and how it has affected aquaculture production. The paper will also centre on the outcome of these effects on the socio-economic activities of the people with the lapses in the production of products. This also includes effects on people's health and poverty conditions. The paper will give the alternative ways of how to solve this nightmare.

### P1-D1-6024

## A study of climate impacts on anchovy population dynamics in the Yellow Sea by individual-based model

Hao **Wei**[1], Yuheng Wang[2], Liang Zhao[2] and Michio J. Kishi[3]

1 Tianjin University of Science and Technology, College of Marine Science and Engineering, 29, 13th Ave., TEDA, Tianjin, 300457, PR China. Email: weihao@ouc.edu.cn
2 Physical Oceanography Lab, Ocean University of China, 238 Songling Rd., Qingdao, 266100, PR China
3 Graduate School of Environmental Science, Hokkaido University, N10W5 Kita-ku, Sapporo, Hokkaido, 060-0810, Japan

To study the climate impact on the anchovy recruitment and production, an individual-based model (IBM) of anchovy was built in the Yellow Sea (YS), coupled with hydrodynamic model POM and coastal lower trophic level ecosystem model NEMURO. Seasonal variation of 3D residual current, water temperature, salinity, turbulent diffusion were simulated by POM using climate forcing to drive transport of nutrients, phytoplankton, zooplankton, eggs and larvae fish of anchovy. Life history and growing of an individual anchovy were considered when it moved between overwinter, spawning and nursering field. Survival fitness theory related to temperature and food was used to describe the swimming behavior of anchovy. Swimming speed relate to the fork length while the swim direction is determined by the gradients of fitness. The growth, reproduction and migration of anchovy were simulated. Numerical experiments were deployed forcing by variation of monsoon, Yellow Sea Warm Current (YSWC) and water temperature according to the climate trends in the YS. The results show that the time and distribution of spring bloom will change with wind speed, thus affect the match/mismatch relationship of anchovy larvae and food (zooplanktons) and influence the recruitment of anchovy. Stronger YSWC induced by stronger winter monsoon will cause a northward movement of anchovy wintering ground. Higher water temperature not only affects the migration of anchovy but also changes its population structure. East Asia monsoon is the major climate factor for anchovy population dynamics in the YS besides over-fishing.

**P1-D1-6074 (*Cancelled*)**

## Factors determining dynamics of highly variable fish stocks and possibilities of its long-range forecasting (taking Northeast Arctic cod as an example)

Andrei S. **Krovnin**, Boris Kotenev, Mikhail Bondarenko and Anatoly Morozov

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17 Verkhnyaya Krasnoselskaya, Moscow, 107140, Russia
E-mail: akrovnin@vniro.ru

The relationships between long-term variations in abundance of various commercial fish stocks and climatic factors only allow assessment of the general tendencies in the population state at decadal and interdecadal time scales. However, the problem of long-range yearly forecasts of stock dynamics has not been solved. In this paper the possibilities of such forecasts, based on empirical and statistical relationships between climatic and biological characteristics, are considered using the example of Northeast Arctic cod. The method suggested the clustering ranking of survival indices (SI), by defining three types of survival conditions: favorable, moderate, and unfavorable. The year-class strength is determined mainly by three factors: spawning stock biomass, wind conditions during the winter-spring period of spawning, and weighted annual water heat content in the spawning and larval development area. Under each type of survival condition the relative role of each factor in determining recruitment abundance differs. The statistical relationship between SI and water heat content allows quantitative estimations of survival conditions 1-2 years in advance. In turn, using the significant correlation between the North Atlantic Oscillation (NAO) index and temperature conditions with lag of 17 years (NAO index leads temperature), it is possible to make quantitative forecast of thermal regime, identify the type of survival conditions, and, finally, develop probabilistic forecasts of recruitment 10 years or more in advance.

**P1-D1-6075 (*Cancelled*)**

## The climatic causes of recent rise of Asian salmon catches and its prospects

Andrei S. **Krovnin**, Nataliya Klovach and George Moury

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17 Verkhnyaya Krasnoselskaya, Moscow 107140, Russia
E-mail: akrovnin@vniro.ru

The growth of the world catch of Pacific salmons started after the climatic regime shift of 1977-1978, and in 2007 it reached 1.03 million t. Under the general increase in abundance of Pacific salmon species during the last years, only pink and chum salmons demonstrate a steady tendency toward catch growth. Recently, the abundance of Asian pink salmon reached record values, providing up to 70-80% of total Russian salmon catches in even and odd years, respectively. In this paper, the climatic causes of this recent increase in abundance of Asian salmons are analyzed. The shift of climatic regime in 1977-1978 accompanied with growth of American salmon stocks practically did not affect Asian stocks. Increase in the Asian salmon abundance started only after 1988 and was the most pronounced in 2005-2009. The analysis of long-term climatic data revealed the regime shift in wintering area of Asian pink and chum salmons at that time, with formation of favorable conditions for their winter survival. Thus, for example, according to the data from counting surveys conducted by SakhNIRO, the 2009 survival of East Sakhalin pink salmon stock in winter was 63.4%, a record. The analysis of the climatic situation developing in the northern North Pacific during the last years produces some evidence of a possible end to the regime favorable for the high survival of Asian salmon stocks in the next 2-3 years. Therefore, the rather sharp decrease in abundance and catches of Asian salmons can be expected.

**P1-D1-6076**

## The North-Atlantic Oscillation and biotical cycles within the Azores region

Tatyana V. Belonenko and Aleksey V. **Koldunov**

Saint Petersburg State University, Faculty of Geography and Geology, Department of Oceanology, 33/35 10th Line, St. Petersburg, 199178, Russia. E-mail: btvlisab@yandex.ru, koldunovaleksey@yandex.ru

Wavelet analysis is applied to satellite estimates of primary production at 42 points across the Azores region (33-43°N, 22-32°W), at 8-day time resolution for a period 4 July 2002 to 29 August 2007. The largest variance was found at time scales of ½, 1, 2, and 4 years found. The existence of an Azorean biological front at 37°N is reflected in the ½-year isopleths and, in turn, they themselves provide information on the spatial-temporal variability of the front. The North Atlantic Oscillation (NAO) index is taken as an indicator of the atmosphere forcing that determines biological environment variability. A stable relation is found between the primary production variability and the NAO around the Azores. Wavelet analysis of monthly NAO index values for 1950-2008 years reveals multi-scale structure of the NAO variability, as well the presence of ½-, 1-, 2-, and 4-year cycles during the time span 2002-2007 years. Primary production variability at the 6 sites of the Azores region were compared with each other, as well with the respective NAO index cycles. At any time scale, the intensity of variability is strongest in the north of the region.

Correlation between primary production biotical cycles and NAO at different points of the region was estimated. For ½-year cycles, the primary production/NAO relationship is rather complicated, evidencing that, along with effects of NAO, some dynamical factors may play a role, including water advection and mixing. Cross-correlation coefficients have been calculated for all cycles of NAO and primary production.

**P1-D1-6102**

## Global warming effects on a Mediterranean ecosystem: A trophic modeling approach on the Bonifacio Straits Natural Reserve (Corsica, France)

Camille **Albouy**[1], François Le Loc'h[2], Jean M. Culioli[3] and David Mouillot[1]

1 Université Montpellier II Place, Eugéne Bataillon Laboratoire, ECOLAG UMR, 5119 34090, Montpellier, France
E-mail: albouycamille@gmail.com
2 UMR EME, IRD, Avenue Jean Monnet, BP 17, Centre de Recherche Halieuthique Méditerranéenne et Tropicale, Sète, 34203, France
3 O.E.F Base Technique et Scientifique de la Rondinara, BP 507, Bonifacio, 20169, France

Human activities have resulted in unprecedented threats on coastal marine ecosystems including direct or indirect effects. Indeed, major changes in exploited biological assemblages and ultimately biodiversity loss may disrupt ecosystem functioning and then alter the sustainability of goods and services provided by marine ecosystems to humanity. Global change may be considered as an important modification source for abiotic parameters such as temperature but may also provoke drastic shifts in species assemblages and modify trophic transfer efficiency. Here we aim to show that the impact temperature can affect the trophic network and structure. This critical question was investigated in the Bonifacio Straits Natural Reserve (BSNR). An Ecopath model was created, including 32 trophic compartments covering detritus, primary producers, pelagic species, and demersal and benthic invertebrates and fishes. To study the influence of temperature increase we built four Ecopath models for different periods (2001, 2006, 2050, 2100). For temperature forecasting, our simulations were based on an ocean modeling approach conduct by Somot *et al.* (2006). They constructed a predicting model based on a climate change IPCC-A2 scenario. Then we have compared the main trophic indicators after the temperature increase in order to find a system response. Some network trophic analyses were implemented between different models in order to find keystone species and their dynamics in regards to global change. Our results suggest that global change, may modify trophic structures of exploited ecosystems and that a trophic modeling approach is an appropriate tool to anticipate such cascading and non-trivial effects.

**P1-D1-6103**

## Current divergences and enhanced biological production zones in the Japan Sea according to satellite observations

Dmitry K. **Staritsyn**

Saint Petersburg State University, Faculty of Geography and Geoecology, Department of Oceanology, 33/35 10th Line, St. Petersburg, 199178, Russia. E-mail: d_starik@mail.ru

The problem of distribution of biological production within different dynamical formations is of interest from both purely biotic and fishery application viewpoints. This paper considers the current divergence flow fields and the primary production (PP) in the Japan Sea based on satellite altimetry and biological data. The paper provides hydrodynamic interpretation of the remote altimeter and biotic measurements, detects the patterns of spatial-temporary variability in PP-fields, and describes and compares dynamical and biological fronts in the Japan Sea. The dependence between the year-averaged location of the biological and physically dynamical fronts is shown to be unstable. A more close relation between these fronts may be observed in the central sea during the monsoon circulation change, as well in the western shelf influenced by Primorskoe and North-Korean currents. Estimates are given of the PP and their divergence fields. We suggest that PP-divergence is caused by action of the warm Tsushima Current. The current-born eddies or waves and the production do not spread all over the sea, but their effect is associated with the zone of interaction (front) with the Japan Sea proper waters. In the south and southeast, the full PP-flow divergence zones are intermittent with convergence zones, probably because of gradient-eddy wave manifestations.

**P1-D1-6114**

## Ignorant academic or a sage fool? Using prior beliefs to forecast climate effects on reef fish communities

M. Aaron **MacNeil**

Australian Institute of Marine Science, PMB3 Townsville MC, Townsville, QLD, 4810, Australia. E-mail: a.macneil@aims.gov.au

What will happen to reef fish communities in the future? Will they persist? Or die? What kinds of statements can we make about what is most likely to happen? Often we simply want to know: what is our best guess about some future state of the world? Quantifying belief requires both a formal statement of experience as well as the capacity to revise ideas as new information becomes available – an empirical approach to understanding the world. Reef fish depend fundamentally on hard coral and, as coral reefs are threatened by global warming and ocean acidification, there is a consequential risk of declines in many reef fish communities. But which ones? And by how much? Using a unique set of long-term data I show how monitoring programmes can be used to annually update expectations about future climate disturbances, quantifying my own beliefs about what will happen to reef fish functional groups on the Great Barrier Reef. These explicit and subjective forecasts are compared to ignorant, objective forecasts to demonstrate the predictive effectiveness of utilizing beliefs in a quantitative framework.

**P1-D1-6126**

## Changes of increase growth rates and fecundity of the Gizhiga-Kamchatka herring (*Clupea pallasii* Valenciennes, 1847), living in a northeast part of Sea of Okhotsk in connection with fluctuations of a water temperature benthic layer around their wintering grounds

Andrey A. Smirnov[1], Alexey V. **Vakatov**[1] and Alexander L. Figurkin[2]

[1] Laboratory of Commercial Marine Fish, Magadan Reseach Institute of Fisheries and Oceanography, 36/10 Portovaya, Magadan, 685000, Russia. E-mail: alexvakatov@mail.ru

[2] Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), 4 Shevchenko Alley, Vladivostok, Primorsky Kray, 690950, Russia

The analysis of variability of length increase rates and fecundity of the Gizhiga-Kamchatka herring in connection with water temperatures of the benthic layer around their overwintering grounds was the purpose of the conducted research. The Gizhiga-Kamchatka herring inhabit the northeast Sea of Okhotsk and winters on a northeast slope of TINRO hollow, between 57º50-59 º00 N' (Melnikov, Loboda, 2004). In April, the herring start to migrate from their overwintering sitesto their spawning locations, which are located at northern coast of the Shelihova Gulf. Analysis was carried out on 23,9 thousand fish collected between 1987 and 2009. We carry out a comparative analysis of body length by age group from individuals caught during the spring and autumn. The rate of change in length for each age was calculated, and also fecundity was noted. The water temperature (x) of the benthic layer on the wintering grounds is shown to influence the rate of increase in the length (y) the Gizhiga-Kamchatka herring, which is expressed by the equation $y=-17{,}795x^2+11{,}061x-0{,}2453$ with a correlation, $r=0.9062$. Connection between water temperatures and fecundity is also investigated with the strongest relationship observed for younger age group fish. Thus, in years with warm winters, the increase in length of the Gizhiga-Kamchatka herring promotes an increase in the biomass of the stock. In abnormally cold years, the rate of body length increase is reduced, at time with zero recorded growth and fecundity.

**P1-D1-6151**

## Predicting tuna habitat for spatial fisheries management using electronic tags and ocean models

Alistair J. **Hobday**[1], Jason R. Hartog[1], Richard Matear[1], Claire M. Spillman[2] and Oscar Alves[2]

[1] Climate Adaptation Flagship and Wealth from Oceans Flagship, CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, 7001, Australia. E-mail: alistair.hobday@csiro.au

[2] Centre for Australian Weather and Climate Research (CAWCR), Bureau of Meteorology, 700 Collins St., Melbourne, VIC 3000, Australia

Southern bluefin tuna (SBT) are a quota-managed species in the eastern Australian longline fishery, and there is a management need to reduce non-quota capture of this species. We developed a near-real time habitat prediction model for SBT, which has been used since 2003 to support the spatial management of this species throughout the fishery. The predicted distribution of SBT habitat on the east coast of Australia is based on analyses of current satellite sea surface temperatures (SST), sub-surface temperatures from a CSIRO ocean model and pop-up archival tag temperature data for SBT. The model output divides the spatial extent of the fishery into three zones based on the expected distribution of SBT. These predictions are provided to managers of the fishery on a fortnightly basis, and a set of management lines that regulate spatial access to the fishery by longline fishers (based on quota holdings) are updated and distributed. We have also recently incorporated a seasonal forecast model (POAMA) into our habitat model, allowing us to generate predictions of SBT habitat out to 5 months. We compare the skill of this model with real time predictions made during previous fishing seasons. This seasonal forecasting offers both managers and fishers the potential to plan for restrictions, and strategically modify their fishing activities. Finally, we use future ocean predictions from the CSIRO Bluelink ocean model for the period 2062-2064 to consider the change in distribution compared to the present, and explore the potential impact on fishers and managers of the future.

**P1-D1-6176**

## Regional climate change impacts on bigeye tuna (*Thunnus obesus*) catch in the Indonesian Seas

Mega Laksmini **Syamsuddin**[1], Sei-ichi Saitoh[1], Samsul Bachri[2] and Agung Budi Harto[2]

[1] Laboratory of Marine Bioresource and Environment Sensing, Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido, 041-8611, Japan. E-mail: mega@salmon.fish.hokudai.ac.jp
[2] Faculty of Earth Sciences and Technology, Study Program of Geodetic and Geomatic Engineering, Bandung Institute of Technology, Ganesa 10, Bandung, 40132, Indonesia

This study observes regional climate changes of El Niño/La Niña Southern Oscillation (ENSO) and their effects on oceanographic conditions, such as current dynamics and upwelling, and how these relate to the distribution and catch of bigeye tuna (*Thunnus obesus*) in the Indonesian Seas. We utilize CTD (Conductivity Temperature Depth) data, Sea Surface Height Anomaly (SSHA) of TOPEX/POSEIDON (T/P) altimetry, Sea Surface Temperature (SST) NOAA/AVHRR satellite images and bigeye tuna catch. Data analysis are taken from 1997 to 2000 which represent the El Niño (April 1997 – June 1998) and La Niña (July 1998 – June 2000) events. The results show that during El Niño, negative SSHA followed by cold SST (<29ºC) related to higher bigeye tuna catch (hook rate above 0.68). Conversely during La Niña, positive SSHA followed by warm SST (>29ºC) related to lower bigeye tuna catch (hook rate below 0.68). Negative (positive) SSHA during El Niño correlates with shallower (deeper) thermocline. Shallower thermocline lifts fishing layer to the surface so that increases bigeye tuna catch on long line purse on this layer. This answer optimal catch during El Niño compare to minimal catch during La Niña. The increasing bigeye tuna catch significantly occurs on the locations where intensified currents, confluence region, convergent and divergent currents, meandering currents, eddies, and westward upwelling Rossby wave propagation are evident. This study concludes that there are still many potential locations that have not been searched optimally. We recommend that the scientific methods considering oceanographic factors as proxies for fish stock assessment should be performed in the future.

**P1-D1-6184**

## 18.6-year period moon-tidal cycle in ocean/climate and its impact on climate/ecosystem predictability

Ichiro **Yasuda**[1], Satoshi Osafune[1], Shunsuke Konda[1], Sachihiko Itoh[1] and Hiroyasu Hasumi[2]

[1] Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo, 164-8639, Japan
E-mail: ichiro@ori.u-tokyo.ac.jp
[2] Center for Climate System Research, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8568, Japan

Bi-decadal variability that is synchronized with 18.6-year period moon-tidal cycle is found in various parts of the ocean and for different climate variables and indices, *e.g.* water-mass variability in the subarctic North Pacific, especially near the strong diurnal tide regions as Kuril Straits and Aleutian Islands, and in long-term climate indices such as the Pacific Decadal Oscillation (PDO), El-Niño and Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO) based on proxy-reconstructed records. Climate and ocean model experiments with locally enhanced vertical mixing around Kuril Straits show that tidal mixing and its variability could generate bidecadal variability in the ocean and the climate. Possible explanation linking the tidal mixing and ocean/climate is presented along with discussions on the impact on potential predictability of ocean/climate/ecosystem using this external forcing of 18.6-yr oscillation and related low-frequency variability.

**P1-D1-6189**

## The fluctuations of solar activity on catch data of mullet and eel

Chih-Chieh **Hsu**[1], Chih-Wei Chang[2], Chia-Hui Wang[1], Yuan-Mou Chang[3], Chen-Feng You[1] and Wann-Nian Tzeng[4]

[1] Earth Dynamic System Research Center, National Cheng Kung University, Tainan, Taiwan, ROC. E-mail: hsucc@mail.com.tw
[2] National Museum of Marine Biology and Aquarium, Pingtung, Taiwan
[3] Department of Ecoscience and Ecotechnology, National University of Tainan, Tainan, Taiwan, ROC
[4] Institute of Fisheries Science, College of Life Science, National Taiwan University, Taipei, Taiwan, ROC

Annual catch data of fry of *Mugil cephalus* and *Anguilla japonica* recruited to the estuaries of Taiwan from 1966 to 2008 were analyzed in association with solar activity. The solar activity and *A. japonica* catches demonstrated approximately synchronous oscillations while the peak catches of *M. cephalus* showed 5-year lag to the 11-year period of solar activity. These findings reveal the significant correlation between solar activity and the fry catch data of both species. However, the mechanism of the solar activity affect on the climate fluctuations and marine system needs further study.

**P1-D1-6195**

## Larval dispersal, overwinter mortality, and climate change: Forecasting range shifts of a sub-tropical fish species in a western boundary current system

Jonathan A. **Hare**[1], Mark J. Wuenschel[2] and Matthew E. Kimball[3]

[1] National Marine Fisheries Service, Northeast Fisheries Science Center, Narragansett, RI, 02882, USA. E-mail: jon.hare@noaa.gov
[2] National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA, 02543, USA
[3] School of Renewable Natural Resources, Louisiana State University AgCenter, Baton Rouge, LA, 70803, USA

Winter severity is an important factor regulating population abundances in mid-latitudes. For marine species with dispersive life histories, planktonic stages are often transported well poleward of the adult range during summer months. These young stages either migrate back to a winter range or perish owing to hypothermal conditions during fall and winter. Along the east coast of the United States, larvae of sub-tropical species are supplied to continental shelf habitats as far north as Nova Scotia, Canada. However, the northern range of many of these species is 100 to 1000 km's to the south. The northern most range of many of these species is determined by the northernmost latitude of tolerable temperatures for overwinter survival of juveniles. We use this mechanistic hypothesis to forecast climate effects on range for one sub-tropical species: the gray snapper (*Lutjanus griseus*). Based on experiments of thermal tolerance and principals of bioenergetics, lower lethal temperatures (acute) and degree-day criteria (chronic/prolonged) are established for the minimum thresholds of juvenile gray snapper survival over the short (days) and long (months) term. Using a statistical downscaling approach, these thresholds are estimated from an ensemble of IPCC AR4 models under different climate scenarios along the latitudinal gradient of the U.S. East Coast. The results are forecasts of gray snapper northern most range under different climate scenarios. We use this species specific forecast to develop a conceptual model of the climate-induced range extensions of sub-tropical species along the east coast of the U.S.

**P1-D1-6199**

## Do we know the potential impacts of global climate change on fishing nations?

Joe **Scutt-Phillips**[1], Graham M. Pilling[1], Lisa J. Readdy[1], John K. Pinnegar[1] and Nicholas K. Dulvy[2]

[1] CEFAS, Pakefield Rd., Lowestoft, Suffolk, NR33 0HT, UK. E-mail: joe.scuttphillips@cefas.co.uk
[2] Department of Biological Sciences, Simon Fraser University, Burnaby, BC, V5A 1S6, Canada

The potential impact of future climate change on nations that rely on fisheries for protein, income and employment has major implications. Whilst previous 'vulnerability' analyses have indicated geographic areas of key concern, there has been little examination of the uncertainty arising from potential alternative climate change scenarios, where the intensity and global distribution of impacts may vary significantly.

Using UK NERC QUEST- 'Global Scale Impacts' project outputs, we calculate future vulnerability and potential impacts for over 200 countries. A suite of metrics is used for Exposure, Sensitivity, and Adaptive Capacity, relating these to future temperature change for each country in different fishery catch components (within Exclusive Economic Zones, high seas areas, and from freshwater, including aquaculture). Consistent adaptive capacity projections are employed from SRES socio-economic storylines. A wide range of climate change scenarios and Global Climate Models are explored to better understand and present the uncertainty important to policy makers. Extending the analysis, we examine the impact of more 'biologically complex' temperature/fish productivity scenarios on results. Potential impacts on specific fishery sectors through other climate impact pathways are also explored, such as that of future country-level water-stress scenarios on freshwater fisheries.

This vulnerability analyses provides a geographic focus for future work, the influence of non-fisheries sector climate pathways on results, and identifies areas where a current lack of knowledge on processes and impacts reduces our understanding of detailed climate impacts on fish and fisheries.

**P1-D1-6208**

## Analyzing warm and cold climate phases to understand differences in survival and connectivity of larval cod: Possible implications for climate change

Trond **Kristiansen** and Kenneth Drinkwater

Institute of Marine Research, P.O. Box 1870 Nordnes, Bergen, 5817, Norway. E-mail: trond.kristiansen@imr.no

Environmental variation can cause significant fluctuations in the survival of larval fish and plankton. Understanding these fluctuations is critical for developing more accurate fisheries models, which are needed for scientific, socioeconomic research, and developing strategies for managing the effects of climate change. In the absence of complete, high-resolution climate models, we can learn from retrospective analyses of warm and cold periods. During the 1970s the North Atlantic (NA) Ocean experienced a general cooling period, while the 1990s was characterized by an intense warming period. By contrasting these two phases of the NA, we can analyze and observe how cold and warm periods affect ocean currents and the distribution of heat, and how such changes propagate through trophic levels from primary production to top-level fish predators. Warm and cold phases had a strong impact in the timing of spring bloom and thereby the production of food for larval fish. Differences in climate can also alter the general ocean currents, leading to variations in the drift trajectories between warm and cold phases. Here, we combine a mechanistic individual-based model (IBM) with a high-resolution three-dimensional physical and biological model (ROMS+BIOFASHAM) to explore how the climate in the 1970s and the 1990s caused differences in modeled larval cod growth, survival, drift, and connectivity between spawning and nursery grounds along the coast of Norway. Based on these results, we describe differences in ecosystem properties in cold and warm periods and how these patterns may relate to cod recruitment in a future changing climate.

**P1-D1-6221**

## An example of estimating future Bering Sea northern rock sole productivity from statistical downscaled IPCC models and its effect on management

Thomas Wilderbuer, Nicholas A. **Bond** and William Stockhausen

Joint Institute for the Study of Atmosphere and Ocean (JISAO), University of Washington, 7600 Sand Point Way NE, NOAA/PMEL, Seattle, WA, 98195-4925, USA. E-mail: nicholas.bond@noaa.gov

There is an increasing interest in forecasting the implications of climate change on the production of marine fish. These analyses involve five steps: 1) identification of mechanisms underlying the reproductive success, growth and distribution of major fish and shellfish populations; 2) assessment of the feasibility of down-scaling implications of IPCC scenarios on regional ecosystems to select environmental indicators; 3) evaluation of climate model scenarios and select IPCC models that appear to provide valid representations of forcing for the region of study; 4) extracting environmental indicators from climate scenarios and incorporating indicators into projection models for fish and shellfish; and 5) evaluation of the mean, variance, and trend in fish and shellfish production under a changing ecosystem. An example is presented where downscaled estimates of future springtime wind direction from IPCC models and water temperature are used to estimate the impacts of climate change on cross-

shelf transport of northern rock sole (*Lepidopsetta polyzystra*) larvae and somatic growth in the Bering Sea. A management strategy evaluation is performed to discern the performance of our current management system given the IPCC models output of future climate. Results show climate change may result in a modest increase in the frequency of strong year classes of northern rock sole through 2050.



### P1-D1-6263

## The impact of climate change on the fishery ecosystems in the Taiwan Strait and their responses

Shengyun Yang[1] and Qiulin **Zhou**[2]

[1] Marine and Environment Institute, Xiamen University, PR China
[2] Third Institute of Oceanography, State Oceanic Administration, 178 Daxue Rd., Xiamen, Fujian, 361005, PR China
E-mail: zhou@public.xm.fj.cn

The paper studies the impact of climate change on the fishery ecosystems in the Taiwan Strait and their responses in terms of sea water rise, precipitation, the change of land runoff and sea currents, as well as sea the episodes of level rise and El Niño. These studies have revealed that the rise of sea temperature has impact on the distribution of fishes in the Taiwan Strait and its adjacent waters. Before 1980s, there were 366 species of fishes in the northern Taiwan Strait. Since 1990s, only 246 species of fishes were recorded, a decrease of 120 species. In addition, 13 new species of fish were recorded in the Taiwan Strait, all being warm waters species. Those fish that used to be landed in the southern Taiwan Strait are now caught in the northern Taiwan Strait. Climate change also impacts the community structure and biomass of plankton in the upwelling fishing grounds in the southern Taiwan Strait. The change of dominant species such as planktonic copepods will have direct impact of the harvest of planktivorous fishes. The decline of fishery population due to the change of community structure induced by the climate change will have more serious and lasting impacts than overfishing. The studies have also revealed that the rise of sea temperature will change the time of the fish migrations and the change in circulation will impact the migration route of fishes. The circulation may also affect larval drift, which if they did not reach the nursery grounds could cause disaster to fish population. El Niño events have led to the change of the Changjiang River runoff and marine environmental conditions and impacts on the temporal and spatial shift of coastal spawning and feeding grounds, and larval development off Zhejiang Province. The paper concludes by making recommendations to counter the impacts of climate change on the ecosystems in the Taiwan Strait, such as giving priority to basic research, long-term and periodic ecosystem monitoring, the impact of coastal economic and social development on the ecosystems in the climate changes scenarios and the responses of marine fisheries to climate changes.

### P1-D1-6272 (***Cancelled***)

## Acoustic observation of living organisms reveals the oxygen minimum zone

Arnaud **Bertrand**[1,2], Michael Ballón[1,2] and Alexis Chaigneau[2,3]

[1] Institut de Recherche pour le Développement (IRD), UMR212 EME, CRH, Av. Jean Monnet, BP 171, 34203, Sète, France
E-mail: Arnaud.Bertrand@ird.fr
[2] Instituto del Mar del Perú, Esquina Gamarra y Gral. Valle s/n, Apartado 22, Callao, Lima, Peru
[3] Institut de Recherche pour le Développement, IPSL/LOCEAN, UPMC/CNRS/IRD/MNHN, 4 Place Jussieu, Case 100, 75252, Paris, Cedex 05, France

Oxygen minimum zones (OMZs) are expanding in the World Ocean as a result of climate change and direct anthropogenic influence. OMZ expansion greatly affects biogeochemical processes and marine life, especially by increasing greenhouse gas production and constraining the vertical habitat of most marine organisms. Currently, monitoring of the upper limit of the OMZs relies on heavy sampling protocols, causing poor spatial resolution. Here we show that routine underwater acoustic observations of the vertical distribution of marine organisms allow a precise determination of the upper limit of the OMZ. We used this high-resolution information in the Eastern South Pacific to document mesoscale and submesoscale features that structure marine ecosystems. We also estimate the habitable volume for the world's most exploited fish, the Peruvian anchovy (*Engraulis ringens*). Horizontally, anchovy distribution is constrained by the offshore extension of cold coastal waters originated from upwelling cells. Vertically, the range of distribution of anchovy is limited by the OMZ. This method can be implemented on any platform (*e.g.*, research vessel, commercial vessels, instrumented buoys) equipped with acoustic echosounders and allows revisiting historical acoustic data for the reconstruction of spatiotemporal

dynamics of the upper limit of the OMZ. Our approach is a novel way of studying the impact of physical processes on marine life and extracting valid information about the pelagic habitat and its spatial structure, a crucial aspect of Ecosystem-based Fisheries Management in the current context of climate change.

**P1-D1-6283**

## Climate-driven, bottom-up control of North Sea herring recruitment

Marc **Hufnagl**[1], Myron A. Peck[1], Mark Dickey-Collas[2], Richard D.M. Nash[3] and Thomas Pohlmann[4]

1 Institute of Hydrobiology and Fisheries Science, Center for Marine and Climate Research, University of Hamburg, Olbersweg 24, Hamburg, D-22767, Germany. E-mail: marc.hufnagl@uni-hamburg.de
2 Wageningen Institute for Marine Resources and Ecosystem Studies, P.O. Box 68, 1970 AB IJmuiden, The Netherlands
3 Institute of Marine Research, P.O. Box 1870, Nordnes, Bergen, 5817, Norway
4 Institute of Oceanography, Center for Marine and Climate Research, University of Hamburg, Bundesstr. 53, Hamburg, 20146, Germany

Recent recruitment failures of North Sea herring (*Clupea harengus*) appear to stem from processes acting during the overwintering period as young larvae drift from spawning grounds to juvenile nursery areas. We performed long-term (1970-2005) 3-D biophysical, individual-based model (IBM) simulations to examine how climate-driven bottom-up factors may impact overwinter larval survival and recruitment variability of the different spawning components of this species in this region. The physiological-based larval foraging and growth IBM incorporated data collected from a large number of laboratory and field studies allowing a species-specific parameterization and extensive validation exercises. Field growth rates agreed well with modelled growth rates when realistic prey concentrations were used as model inputs. Model results suggest that the intensity and spreading of the North Sea autumn zooplankton bloom might be an important driver for overwinter survival. Furthermore, modelled and observed sizes of larvae after the overwinter period agreed well from 1990 to 2005 whereas the model under predicted lengths observed in earlier years. This might be due to either increasing rates of mortality and/or decreasing prey quality since 1990. The North Sea underwent a 'regime shift' around 1988 to 1990 including changes in plankton composition. The overall effects of such a change are unclear. However, bottom-up factors appear to more strongly regulate recruitment potential since 1990 although these changing environmental impacts were initially masked by increasing levels of spawning stock biomass, as the stock rebuilt after the 1970s collapse.

**P1-D1-6289**

## Projected effects of global warming on corals in seas close to Japan

Yumiko **Yara**[1], Masahiko Fujii[1], Yasuhiro Yamanaka[1], Naosuke Okada[1], Hiroya Yamano[2] and Kazuhiro Oshima[1]

1 Faculty of Environmental Earth Science, Hokkaido University, N10 W5 Kita-ku, Sapporo, 060-0810, Japan
E-mail: yara@ees.hokudai.ac.jp
2 Center for Global Environmental Research, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki, 305-8506, Japan

Global warming and associated increases in sea water temperature are considered to be crucial factors for future corals, by inducing coral habitat migration toward higher latitudes and intensifying chances for coral bleaching and death. Using projected monthly-mean sea surface temperature in the simulations of the climate models and simplified indices, we quantitatively evaluate the potential effects of global warming on corals in seas close to Japan. We employed "the 20$^{th}$ century climate in coupled models" (20C3M) simulations from 1900 to 1999, and simulations from 2000 to 2099 under a middle-range IPCC greenhouse gas emission scenario (A1B), based on the 23 CMIP3 (Coupled Model Intercomparison Project phase 3) models. Our result shows that the temperature-determined northern limit of subtropical and temperate coral habitats will migrate northward, by around ~100km, by the end of the 21$^{st}$ century. In the Ryukyu Islands located in the southwestern part of Japan, on the other hand, both frequency and area of coral bleaching or death are expected to be intensified. Particularly, intermittently experienced high water temperatures which result in bleaching or death of present-day corals, will appear perpetually in the latter half of the 21$^{st}$ century. Uncertainties of the projected effects of global warming on corals will be discussed.

**P1-D1-6354 (*Cancelled*)**

## Extreme climatic events and the dynamics of the Peruvian small pelagic fish environment

Miguel **Ñiquen**[1], Marilou Bouchon[1] and Milena Arias-Schreiber[2]

[1] Instituto del Mar del Perú (IMARPE), Esq. Gamarra y Gral.Valle s/n, Chucuito, Callao, Peru. E-mail: mniquen@imarpe.gob.pe
[2] Leibniz Center for Tropical Marine Ecology, Fahrenheitstrasse 6, Bremen, 28359, Germany

Small pelagic fish currently comprise about one quarter of the global fish catch and are extremely sensitive to climate-ocean variability. The Peruvian pelagic fishery takes advantage of the massive abundance of these small fish and thus is an important indicator on changes in species distribution and abundance due to environmental variability. Beyond seasonal changes, the Peruvian pelagic environment has to put up also with interdecadal (E Niño Southern Oscillation or ENSO events) and multidecadal (El Niño and La Niña periods) variability. This research describes long-term changes in the dominant catches of the Peruvian small pelagic fishery after the three last strong ENSOs from 1972-73, 1983-84 and 1997-98. Due to their time-span, intensity of the warm sea surface temperature anomalies and vast impacts along the Peruvian coast, these mentioned ENSOs are classified as extreme climatic events. Results show that after the first strong ENSO in 1972-73, the Peruvian pelagic habitat changed from a high-dominant anchovy to a low-dominant anchovy environment. This feature remained until the ENSO 1982-83, when the low-dominant anchovy changed to a sardine-anchovy environment and switched again to a high-dominant anchovy environment after the 1997-98 ENSO. Although the connection between climate change and the occurrence of strong ENSO events is not clear yet, the environmental and subsequent fishery changes described in this study should be considered in the analysis of future scenarios for climate change.

**P1-D1-6380**

## The impact of climate changes on the distribution and abundance of mackerel in the northwestern Pacific

Sukyung **Kang**[1], Jae Bong Lee[1], Anne B. Hollowed[2], Nicholas A. Bond[3] and Suam Kim[4]

[1] National Fisheries Research and Development Institute, Busan, 619-902, R Korea. E-mail: kangsk@nfrdi.go.kr
[2] Alaska Fisheries Science Center, NOAA, Seattle, WA, USA
[3] Joint Institute for the Study of Atmosphere and Ocean (JISAO), University of Washington, Seattle, WA, USA
[4] Pukyong University, Dayeon3-dong, Nam-gu, Busan, 608-737, R Korea

In recent years, time series of climatic/oceanographic/fisheries data have been examined to assess the impact of climate variability on fisheries resources. In this investigation, we examined potential impact of climate variability on mackerel production in the marginal seas of the northwestern Pacific Ocean. Data sets included time series of catch, recruitment, biomass of mackerel in Korea and Japan, and environmental factors such as temperature, salinity, meridional wind intensity since 1970. Mackerel abundances increased in the mid-1990s and the habitat of mackerel seemed to have expanded to the north with the SST increase. The time series of spawning biomass and recruitment of mackerel showed the discontinuity and significant change in recruitment was found based on correlations with salinity. Recruitment was higher when the winds were greater from the south across the shelf break of the East China Sea. Therefore, we may speculate that when Tsushima Warm Current is strong, chub mackerel larvae are advected into Korean waters, which confirms the relationship between salinity and recruitment success of mackerel. We hypothesize that the recruitment of mackerel is positively influenced by high salinity conditions or warm ocean conditions in the ECS through its influence on the volume of suitable spawning habitat. We forecast the impact of climate change on mackerel production by imbedding time trends in the volume of spawning habitat into a stock projection model. The results of stock projection models will improve scientific support for policy and management of mackerel in the Northwestern Pacific.

**P1-D1-6383**

## An assessment of regime shifts in North Pacific ecosystems

Franklin B. **Schwing**, Roy Mendelssohn and Steven J. Bograd

NOAA-Fisheries, Southwest Fisheries Science Center, Pacific Grove, CA, 93950, USA. E-mail: franklin.schwing@noaa.gov

The concept of relatively abrupt, large-scale changes in the state of the atmosphere and ocean, accompanied by a corresponding reorganization of marine ecosystem structure, has garnered considerable attention in recent years both in the scientific literature as well as from the perspective of resource management. These changes, commonly referred to as climate regime-shifts, have particular significance in the North Pacific, where they have been credited with causing major changes in important commercial fish populations, including sardine and salmon, as well as in other ecologically important species. Proper identification of regime shifts is critical to our ability to separate natural and anthropogenic trends in global climate. Understanding the relative timing of these events provides the links from climate variability to ecosystem response, which is important if a predictive capability of the impacts of future climate change is to be developed.

We apply state-space models and other objective methods to characterize the evolution of a number of North Pacific physical and biological observational and model time series, and to provide evidence of past synchronous temporal behavior. In particular, we examine for regime shifts related to those reported in about 1976, 1989, and 1998. Do we see evidence of an abrupt and simultaneous change in the behavior of all time series, as some have reported? Is there a lag between series, evidence of a mechanism or propagation of the regime shift signal? Are such shifts more gradual in some series?

**P1-D1-6389**

## Indices of temporal variability in North Pacific SST from IPCC model future climate scenarios: A hierarchical Bayesian analysis

Francisco **Beltran**[1], Bruno Sanso[1], Ricardo Lemos[2] and Roy Mendelssohn[3]

1 Department of Applied Mathematics and Statistics, University of California, Santa Cruz, CA, 95064, USA
E-mail: roy.mendelssohn@noaa.gov
2 Instituto de Oceanografia, Universidade de Lisboa, Lisboa, Portugal
3 NOAA-Fisheries, Southwest Fisheries Science Center, Environmental Research Division, Pacific Grove, CA, 93950, USA

Historical records of sea surface temperature (SST) in the North Pacific as well as output from five IPCC global climate models corresponding to both, 20$^{th}$ century conditions (20c3m) and 21$^{st}$ century forecasts (SRESAIB), are analyzed using Bayesian methods. Empirical Orthogonal Functions (EOFs) are used to decompose the anomalies of the observational data, and then climate model anomalies are projected onto the observational EOFs. A hierarchical Bayesian model with time-varying parameters is then used to estimate a common temporal pattern. The model is based on the assumption that all six time series, for a given EOF mode, reflect a common baseline, and that the climate models deviate from this baseline according to a time-varying individual model discrepancy. The goal of the project is to extract indices of relevant future temporal variability in SST from the IPCC simulations that can be used in ecosystem models to project the effects of different climate change scenarios on the ecosystem.

# P2 Oral Presentations

**26 April, 11:00 (P2-6119)**

## Global environmental change scenarios for the world's small pelagic fisheries and global fishmeal and oil markets

Gorka **Merino**[1,2], Manuel Barange[1], Christian Mullon[3], Robert Holmes[1], Julia L. Blanchard[4] and Lynda Rodwell[2]

1 Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK. E-mail: gmerin@pml.ac.uk
2 School of Earth, Ocean and Environmental Sciences, University of Plymouth, Drake Circus, 10 Plymouth, PL4 8AA, UK
3 Unite de Recherche Ecosystèmes Marins Exploités, Avenue Jean Monnet, 34200, Sète, France
4 Division of Biology, Imperial College London, London, SW7 2AZ, UK

Fishmeal and fish oil are global commodities traded in international markets, resulting primarily from the reduction of a significant proportion of the global small pelagic fish catches. A network model that captures approximately 85% of the world's fishmeal and fish oil production and trade has been developed and parameterized using trade and catch data (2000-2005). In order to estimate the consequences of climate change on the global production-consumption system, future scenarios need to be generated for this bioeconomic network. Such scenarios must have explicit ecological, management, and demand components. In this contribution the ecological component is determined by predicted changes in the production of the underlying fish stocks, at interannual, decadal and multidecadal time scales. Data and model assumptions are provided from the QUEST_Fish project. Management scenarios consider range from open access to maximum sustainable yield, and consider historical levels of national compliance to regulation. Demand scenarios rely on likely changes in the fisheries sector over the coming decades, as determined by Delgado *et al.* (2003). The work presented pioneers the quantification of future bioeconomic scenarios driven by climate change, economic globalization, global demand for fish products and management efficiency. Preliminary results indicate that the way we manage climate impacts, both at a regional and global level, will determine the sustainability of the world's reduction fisheries, a conclusion that could be extended to other, similarly affected, natural resources. Alternative pathways to sustainability will be outlined.

**26 April, 11:15 (P2-6290)**

## Can there be stable, cooperative exploitation of a transboundary fish stock under climate variability? A game analysis on the Pacific sardine fishery in the California Current

Gakushi **Ishimura**[1,2], Samuel Herrick[3] and Ussif Rashid Sumaila[2]

1 Center for Sustainability Science, Hokkaido University, Kita-ku, Kita 9 Nishi 8, Sapporo, 060-0809, Japan
E-mail: gakugaku@u.washington.edu
2 Fisheries Economics Research Unit, Fisheries Center, the University of British Columbia, AERL, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada
3 NOAA Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA, 92037-1508, USA

The time variant/asymmetric distribution of a fish stock caused by climate variability is one of the challenges facing the cooperative exploitation of a transboundary fish stock. This is particularly characteristic of the Pacific sardine *(Sardinops sagax)* stock, which has exhibited extreme decadal variability corresponding to warm/cold regime shifts of the California current ecosystem (CCS). During the 1930s-1940s, when the CCS was in a warm regime, the Pacific sardine stock supported the largest fishery in the CCS. In the late 1940s, landings started to decline dramatically and the sardine stock shifted southward. The subsequent collapse of the sardine fishery has been attributed to a combination of overfishing and a shift to a cold regime in the CCS. With the onset of a warm regime in the 1970s, the stock started to rebuild and currently ranges from Canada to Mexico, supporting fisheries in all three countries, yet, no transboundary management agreement is in place. Given the eventuality of a CCS cold regime (or even global climate change), and the likely redistribution of the sardine stock, the need for an international agreement seems all the more pressing. Our study applied a three-agent bioeconomic framework, which incorporates environmental effects, to investigate the impact of climate change on sardine stock abundance and geographic distribution. A game theoretic analysis was conducted to evaluate the stability of cooperative exploitation of the sardine stock under various climate variability scenarios. Our results show that climate variability is an obstacle to stable, cooperative exploitation of the Pacific sardine stock by the three countries.

**26 April, 11:30 (P2-6398)**

## Vulnerability of aquaculture to climate change in the Pacific

Timothy **Pickering**[1], Ben Ponia[1], Cathy Hair[2], Paul Southgate[3], Elvira S. Poloczanska[4], Luc Della Patrona[5], Antoine Teitelbaum[1], C.V. Mohan[6] and Michael Phillips[7]

1 Aquaculture Section, Coastal Fisheries Program, Secretariat of the Pacific Community, B.P. D5, 98848 Noumea Cedex, New Caledonia. E-mail: timp@spc.int
2 James Cook University, C/- Northern Fisheries Centre, P.O. Box 5396, Cairns, Queensland, 4870, Australia
3 School of Marine and Tropical Biology, James Cook University, Townsville, Queensland, 4811, Australia
4 Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, P.O. Box 120, Cleveland, Queensland, 4163, Australia
5 IFREMER, Département Lagons Ecosystèmes Aquaculture Durables, BP 2059, 98846 Nouméa Cedex, Nouvelle-Calédonie
6 Network of Aquaculture Centres in Asia-Pacific (NACA), P.O. Box 1040, Kasetsart Post Office, Bangkok, 10903, Thailand
7 The World Fish Centre, Jalan Batu Maung, 11960 Batu Maung, Pulau Penang, Malaysia

Small pond aquaculture has been identified as one of three main regional strategies to help address a growing gap between fish supply and demand in the Pacific island countries, and to build resilience to the effects of climate change upon coastal reef fisheries. But aquaculture will itself be affected by climate change.

This paper provides an assessment of the likely effects of climate change on important aquaculture environments, and on the productivity of aquaculture systems in the Pacific islands region. It has been prepared to equip policy makers, resource managers and aquaculture developers in Pacific island countries and territories with information on how climate change might affect future plans for sustainable aquaculture development.

Projected scenarios for climate change are here matched with published information and expert opinion about aquaculture commodities and the biological tolerances of the high-priority species for aquaculture in the insular Pacific, in order to come up with an assessment of vulnerabilities. Current and projected uses of aquacultured species in the Pacific islands region are described, and recent and potential aquaculture production is summarised. The vulnerability of aquaculture to the direct and indirect effects of climate change are assessed, under the low (B1) and high (A2) IPCC emission scenarios for 2035 and 2100. Projected changes in production across the main aquaculture commodities are summarised, and management measures to help aquaculture adapt to climate change and identify uncertainty are recommended. Gaps in knowledge, and future research needed to build more resilient aquaculture sectors, are identified.

**26 April, 11:45 (P2-6359)**

## Modeling fleet behavior in the Bering Sea pollock fishery under climate change

Alan **Haynie** and Lisa Pfeiffer

NOAA Fisheries, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115, USA. E-mail: Alan.Haynie@noaa.gov

One component of the Bering Sea Integrated Ecosystem Research Project (BSIERP) is a spatial economic model that predicts changes in fishing activity in the Bering Sea pollock fishery that may result from climate change. Models such as the one employed here have been used in the Bering Sea and elsewhere to model how fishers make decisions about where to fish. Commercial fishers choose where to fish based on observable and unobservable characteristics of the area, and the fisher. We model location choice as a function of the expected revenue in an area, fuel and fish prices, distance to an area, vessel characteristics and institutional and environmental conditions. In the Bering Sea pollock fishery, climate variables affect many aspects of the fishing decision. Key among these aspects is the role that climate has on fish location and abundance and the impact that weather plays in daily participation and location choices for smaller vessels. In this paper, we develop and apply a model of the America Fisheries Act pollock catcher processor fleet. The spatial economic model incorporates climate data (*e.g.*, ice cover, SST, wind) into the model, permitting us to determine the relative impact of observable contemporaneous environmental conditions on location choices. We develop a framework to include predictions of changing pollock abundance in the model, which allows us to predict fisher responses to scenarios developed by oceanographic and ecosystem modelers involved in the BSIERP as well as different scenarios for fuel and seafood market conditions.

**26 April, 12:00 (P2-6367)**

## Scenarios for the future: Drivers of change in the Peruvian fisheries sector

Marie-Caroline **Badjeck**[1] and Tania Mendo Aguilar Wosnitza[2]

[1] The WorldFish Center, Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Penang, P.O. Box 500, GPO 10670, Malaysia
E-mail: m.badjeck@cgiar.org
[2] Parque Bartolome Herrera, Calle B 190, Lima, 32, Perú

Peru is the largest producer of fishmeal and fish oil worldwide with the overall production absorbed by aquaculture, one of the fastest growing animal food producing sectors, dominated by China and South East Asian countries. Localized changes in the productivity of Peruvian marine waters induced by climate change and increased climate variability will pose new challenges to the fishery and the aquaculture sectors globally. However, climate change does not occur in isolation of other drivers of change. Processes of environmental, economic, social and political change will affect the Peruvian fishery sector, potentially creating additional vulnerability to climate change. Understanding non-climate drivers of change and creating plausible descriptions of how the future may develop can inform adaptation planning. This paper presents an integrated approach to the construction of fisheries sector scenarios required for the analysis of climate change impacts and adaptation policies in the Peruvian fisheries sector. Through an expert elicitation survey, we identify and analyse the multiple drivers of change faced by the fisheries sector in the past as well as explore future ones. This is followed by a workshop where experts construct future scenarios for the sector for 2050. The results will aid management, planning and policy measures aimed at increasing the capacity of the fisheries sector to face the challenges posed by climate change.



**26 April, 12:15 (P2-6071)**

## The effect of climate change on fishing behaviour in the Eastern Tuna and Billfish Fishery

Ana **Norman-López** and Sean Pascoe

CSIRO Marine and Atmospheric Research, 233 Middle St., Cleveland, Queensland, 4163, Australia. E-mail: ana.norman@csiro.au

Climate change is expected to induce a southern movement of the Eastern Tuna and Billfish Fishery (ETBF) and to impact its abundance with the increase in sea surface temperatures and the strengthening of the East Australia Current. These environmental changes will change the profitability of different areas and species caught within the ETBF and as such result in a redistribution of fishing effort among alternative areas. Furthermore, the magnitude of the effort displacement could induce a relocation of some vessels to more southern ports, which in turn would impact on communities based in the original ports. Understanding the response of fishers to climate change is critical in order to design management plans that protect the resource, provide economic benefits to fishers, and prepare communities for possible employment and income changes. In this paper, we use random utility models to investigate how fishers choose different areas, based on numerous observable and unobservable characteristics of the area and the fisher. We model location choice as a function of the expected revenue in each area, distance to an area, vessel characteristics, current environmental conditions and climate predictions. The climate predictions include physical changes as well as changes in the ETBF abundance and location. These predictions have been obtained from oceanographic and ecosystem climate models. The results from our analysis contribute to an improved understanding of the response of fishers to climate change.

**26 April, 12:30 (P2-6230)**

## Impact of climate change on marine resources food security and local economies in West African countries

Ussif Rashid Sumaila[1], William L. Cheung[2] and Vicky W.Y. **Lam**[1]

[1] Fisheries Centre, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada. E-mail: r.sumaila@fisheries.ubc.ca
[2] School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK

The productivity and maximum catch potential of marine resources of countries in the tropics were shown to be impacted the most under previous projections of climate change studies. The majority of these countries are developing countries, which depend to a good extent on marine fish and invertebrates for their animal protein supply. Furthermore, fishing is the major, and in some cases, the primary available livelihood source for many coastal communities in these countries. The current study aims to assess the impact on the food security and local economies of these countries qualitatively and quantitatively when the maximum catch potential of different fish species changes under various climate change scenarios. In addition, we identified the coastal countries in this region with the highest vulnerability to the change in climate in terms of food security and local economies. Finally, we evaluated the economic efficiency of fisheries in these countries under different management measures for coping and adapting to climate change using cost-benefit analysis (CBA). Thus, the effectiveness of various policy options for managing marine resources, such as establishing marine reserves and reducing fishing capacity under various climate change scenarios, are assessed. Our study will help decision-makers choose the most appropriate management measures for managing the marine resources in West Africa with an aim to secure food supply and enhance local economies under the impact of climate change.

**26 April, 12:45 (P2-6386)**

## Ocean proxies for seafood market variability in the South Brazil Bight

Maria A. **Gasalla**[1], R. Pincinato[1] and I. Belkin[2]

[1] Fisheries Ecosystems Laboratory, Instituto Oceanografico, University of São Paulo, Brazil. E-mail: mgasalla@usp.br
[2] Graduate School of Oceanography, University of Rhode Island, USA

Relationships between environmental factors and fluctuations in seafood market price and quantities in the South Brazil Bight are studied from 1967 to 2007. The collection of data from wholesale market and satellite-based sources allowed for the exploration of seasonal and inter-annual variability. Market data were correlated with time-series of sea surface temperature, climatic indices and some oceanographic anomalies.

Statistical models were applied to explore factors controlling market fluctuations of small pelagics, mackerels, bonitos, swordfish, cephalopods, sharks and croakers, with special attention to categories used for sashimi. Normal supply-demand relationships can be clearly observed for some resources when prices move up as quantities go down. Prices can correlate with supply, demand, and probably with seafood quality, but these factors do not seem to totally explain fluctuation. Rather, some trends appear to be partially linked to the ocean condition, such as sea surface temperature change and the regional long-term warming. Changes in sea surface temperature can also play a significant role in price fluctuations, therefore forecasting models can be further improved by using ocean proxies.

# Day 4 Plenary Oral Presentations

**29 April, 9:05 (P3-6212), Invited**

## Impacts of climate changes and a pragmatic ecosystem-based approach for assessing and forecasting harvest policies under changing climate in Korea

Chang Ik **Zhang**[1] and Jae Bong Lee[2]

[1] Pukyong National University, Busan, 608-737, R Korea. E-mail: cizhang@pknu.ac.kr
[2] National Fisheries Research and Development Institute, Busan, 619-705, R Korea

Climate changes such as global warming, decadal climatic regime shifts and interannual variability of the ENSO phenomenon can affect ocean conditions, and thus affect the functioning mechanism of marine ecosystems and the distribution and abundance of fisheries resources. There has been an increasing trend in sea surface temperatures which has accelerated in last decades in Korean waters. The recent warming trend in the Korean marine ecosystem is associated with a decline in cold-water species (*e.g.* walleye pollock) and an increase in warm-water species (*e.g.* squids, mackerels). This warming trend is also associated with changes in spatial distribution, growth and reproduction of fish stocks such as common mackerel in Korean waters. A pragmatic ecosystem-based approach has been developed for assessing fisheries resources, which evaluates four management objectives: maintaining sustainability, biodiversity, habitat quality, and socio-economic benefits. A number of indicators are used to assess ecosystem status. Target and limit reference points were chosen for each indicator to assess the status of species, fisheries and ecosystems. A forecasting version of this approach is in the developing stages with an aim to forecast impacts of climate changes and/or fishing activities (*e.g.* TAC) on fish and fisheries of an ecosystem. We attempted to apply this approach to the Korean large purse seine fishery.

**29 April, 9:30 (P3-6073), Invited**

## Assessing the adequacy of current fisheries management under changing climate

Éva **Plagányi**[1], Scarla Weeks[2], Tim Skewes[1], Mark Gibbs[1], Elvira S. Poloczanska[1] Ana Norman-López[1], Laura Blamey[3], Muri Soares[3] and William Robinson[3]

[1] CSIRO Marine and Atmospheric Research, 233 Middle St., Cleveland, Queensland, 4163, Australia
E-mail: Eva.Plaganyi-lloyd@csiro.au
[2] Centre for Remote Sensing and Spatial Information Science, The University of Queensland, Queensland, 4072, Australia
[3] Department of Mathematics and Applied Mathematics, University of Cape Town, Private Bag Rondebosch, 7700, South Africa

Climate change is likely to have a significant impact on both target and non-target marine stocks worldwide, with the concomitant need for management strategies capable of sustaining fishing into the future. We use several southern hemisphere fisheries to highlight the likely impacts of climate change at a range of levels, from individual to population responses, as well as ecosystem ramifications. Examples are drawn from polar (Antarctic krill fishery and dependent predator species), temperate (South African east coast linefish community, west coast pelagic fishery, abalone and rock lobster) and tropical (Australian rock lobster) fisheries. Responses of these systems to either past observed environmental changes or postulated future changes are used to deduce some anticipated implications of climate change for fisheries management, including economic impacts and governance considerations. We evaluate the effectiveness of current single-species assessment models, management strategy evaluation approaches and multi-species assessment models as future management tools to cope with likely climate related changes. Non-spatial stock assessment models will have limited ability to separate fishery effects from the impacts of climate change. Single-species management procedure frameworks (with their feedback loops) are predicted to be more successful in terms of detecting and adapting to changes in target stocks. Nonetheless, they will still be limited in their longer-term ability to manage stocks sustainably under changing climate unless they include spatial structure, environmental forcing or a broader ecosystem perspective.

**29 April, 9:55 (P3-5996)**

## Sustainable strategies in a warming climate: Salmon in the Arctic

Jennifer L. **Nielsen**[1], Gregory T. Ruggerone[2], Christian E. Zimmerman[1] and Jamal H. Moss[3]

[1] US Geological Survey, Alaska Science Center, 4210 University Dr., Anchorage, AK, 99508, USA. E- mail: jlnielsen@usgs.gov
[2] Natural Resources Consultants, Inc., 1900 West Nickerson St., Suite 207, Seattle, WA, 98119, USA
[3] NOAA Fisheries, Ted Stevens Marine Research Institute, Alaska Fisheries Science Center, 17109 Point Lena Loop Rd., Juneau, AK, 99801, USA

In the warming Arctic, aquatic habitats are in flux and salmonids are exploring their options. Post-glacial colonization by Atlantic salmon (*Salmo salar*) includes hundreds of populations in Russia, Norway and Finland. Arctic salmon have extended their range eastward as far as the Kara Sea in central Russia. In eastern North America, the northern tip of Quebec seems to be an Atlantic salmon barrier with low freshwater temperatures preventing development. Small populations of Pacific chum (*Oncorhynchus keta*) and pink salmon (*O. gorbuscha*) in Canada's Mackenzie River may survive because these species are less dependent on freshwater habitats and grow rapidly at sea. Adult sockeye (*O. nerka*), coho (*O. kisutch*), Chinook (*O. tshawytscha*), pink and chum salmon have sporadically been caught in domestic and subsistence fisheries throughout the Alaskan Arctic. Spawning populations, however, are rare and limited to pink salmon in Arctic drainages north of Point Hope and reports of chum salmon spawning in drainages in the northwestern Beaufort Sea. Physical and biological conditions can play a critical role in establishment of self-sustaining populations. While broad-scale predictive models of climate change in the Arctic exist for both marine and freshwater habitats, we have little to judge the temporal and spatial scales of change in habitat and biological adaptations necessary for persistence of self-sustaining populations of salmon in Arctic waters. We describe potential barriers to colonization based on current conditions and explore what we know and do not know about patterns of climate change in the Arctic potentially affecting sustainability in salmon.

**29 April, 10:10 (P3-6395)**

## Moving from fisheries oceanography towards ecosystem oceanography for building scenarios for marine ecosystems under anthropogenic and natural forcing in the XXI Century

Philippe **Cury**

IRD, UMR EME 212, CRH (Centre de Recherche Halieutique Méditerranéenne et Tropicale) or IRD - IFREMER and Université Montpellier II, Avenue Jean Monnet, BP 171, 34203 Sète Cedex, France. E-mail: philippe.cury@ird.fr

Overexploitaton and climate change are increasingly causing unanticipated changes in marine ecosystems, such as higher variability in fish recruitment and shifts in species dominance. An ecosystem-based approach to fisheries attempts to address these effects by integrating populations, food webs and fish habitats at different scales. Ecosystem models represent indispensable tools to achieve this objective. However, a balanced research strategy is needed to avoid overly complex models. Ecosystem oceanography represents such a balanced strategy that relates ecosystem components and their interactions to climate change and exploitation. It aims at developing realistic and robust models at different levels of organization and addressing specific questions in a global change context while systematically exploring the ever-increasing amount of biological and environmental data. Those models intend to develop, to integrate, and to promote the development of scenarios for marine ecosystems under anthropogenic and natural forcing in the XXI Century.

**29 April, 10:25 (P3-6391)**

## The challenges of developing fisheries stock assessment approaches, harvest control rules, and management strategies to satisfy and adapt to increasingly complex management objectives in a changing environment

James N. **Ianelli**

NOAA-Fisheries, Alaska Fisheries Science Center, Resource Ecology and Fisheries Management Division, Bldg. 4, 7600 Sand Point Way NE, Seattle, WA, 98115, USA. E-mail: jim.ianelli@noaa.gov

The task of applying the best available information for fisheries management advice is growing rapidly as the number of stocks or stock components considered increases. Stock assessments are highly uncertain; adding links through consumption observations and environmental parameters generally inflates the uncertainty on stock dynamics. From the fisheries harvest side, transparency of activities is generally better but there remain serious information gaps for managers (*e.g.*, lack of observer data, information on costs, fishery responses to different types of regulations, *etc.*). Adding non-stationary dynamics to both of these sets of processes (at the ecosystem and fisheries management levels) further complicates predictions beyond near-term trends. Forecast methods exist that distill complex adaptations and interactions and perform well in predictive tests. However, these methods generally ignore processes typical in annual fisheries decision making including how broad-reaching management systems respond to new information. In this paper, we propose a fisheries management scenario where routine assessments are tested periodically for productivity changes that may affect estimated stock "target" levels. This provides a way for managers to evaluate the consequences of applying periodic adjustments to such reference points. We contrast this with typical stock assessment models (which use up-to-date "best available" data) linked to management control rules (for setting quotas) that are revised periodically based on extensive management strategy evaluations that typically ignore productivity changes.

**29 April, 11:00 (P3-6335)**

## Networking across global marine 'hotspots'

Gretta **Pecl**[1], Alistair J. Hobday[2], Stewart Frusher[1], Warwick Sauer[3] and participants of Workshop 5

1 Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Hobart, Tasmania, 7001, Australia
E-mail: Gretta.Pecl@utas.edu.au
2 CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania, 7001, Australia
3 Rhodes University, P.O. Box 94, Grahamstown, 6140, South Africa

The enormity of the global adaptation challenge is demonstrated by climate predictions that indicate a rise in marine waters of up to 4°C by the end of this century. Regions exposed to the most rapid warming are expected to provide the earliest information on impacts, assessments of the ability of models to capture climate change and evaluation of the success of adaptation measures. These global hotspots will be sentinels of change and pivotal to our understanding for managing change. The *Networking across global marine hotspots* workshop was designed to bring together researchers located in these hotspots to summarise information currently emerging on climate change impacts and to discuss the potential for developing a global network of scientists, policy makers and managers working in marine hotspots. Such a network would provide a global forum for communication, collaborations and combined learning that would capitalise as efficiently and rapidly as possible on emerging information. Traditionally we have looked to the past to generate hypotheses of future species, ecosystem and fishery behaviour. However, as we move towards no-analogue futures, the nature and pace of climate change is eroding the value of historical information. Research from hotspots would provide greater knowledge for managers and communities including increased confidence in the models and proposed adaptation options. Adaptation to the impacts of a 4°C warming will be a complex, difficult and multi-dimensional undertaking, but one that is a necessary for lessening the realised impacts of climate change. Cooperative learning in this endeavour will be essential.

**29 April, 11:15 (P3-6240)**

## Scenario based models for predicting stakeholder responses to a changing climate: A case study for the Eastern Bering Sea

Anne B. **Hollowed**[1], Nicholas A. Bond[2], Alan Haynie[1], James N. Ianelli[1] and Franz J. Mueter[3]

[1] NOAA-Fisheries, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115, USA
E-mail: Anne.Hollowed@noaa.gov
[2] University of Washington, Joint Institute for the Study of Atmosphere and Ocean, Box 354925, Seattle, WA, 98195, USA
[3] School of Fisheries and Ocean Sciences, 315 Lena Point, 17101 Pt. Lena Loop Rd., Juneau, AK, 99801, USA

The North Pacific Research Board and the National Science Foundation are funding a large interdisciplinary research program to provide forecasts of the impacts of climate change on the Eastern Bering Sea ecosystem. These forecasts require scenarios of future stakeholder engagement and decision rules to simulate how stakeholders will respond to a changing environment. A retrospective analysis is conducted to explore how fishers and policy makers shifted their strategies in response to past changes in climate and societal pressures. Three factors emerged as the key drivers influencing stakeholders and managers: changes in socio-economic conditions, changes in fisheries management, and changes in scientific understanding. Stakeholder decision rules are developed to predict responses to legal or economic constraints governing commercial fishing in the region. Ecosystem scenarios are derived by statistical downscaling climate/ocean forcing for the region from Intergovernmental Panel on Climate Change (IPCC) model output. The scenarios of stakeholder responses are developed for the following stressors: a) changes in the demand for seafood, b) increasing fuel prices, c) resource partitioning due to species interactions, fisheries interactions, or Marine Spatial Planning. Scenarios of shifting ecosystem conditions will include: a) shifting zoogeographic boundaries due to climate change, and b) shifting reproductive potential due to changing climate. The trade-offs and risks associated with each stakeholder scenario are discussed. The decision rule approach provides a foundation for communicating with stakeholders and attempts to initiate discussions of more complex adaptive and holistic management and modeling approaches.

**29 April, 11:30 (P3-6316)**

## Incorporating climate changes into population dynamic modelling: an individual-based modelling approach for the pronghorn spiny lobster (*Panulirus penicullatus*) in eastern Taiwan

Yi-Jay **Chang**[1], Chi-Lu Sun[1], Yong Chen[2] and Su-Zan Yeh[1]

[1] Institute of Oceanography, National Taiwan University, Taipei, 10617, Taiwan, ROC. E-mail: chilu@ntu.edu.tw
[2] School of Marine Science, University of Maine, Orono, ME, 04469, USA

One of the most challenging issues in fisheries management is to evaluate the effects of fishing in the context of a changing environment. Using the pronghorn spiny lobster (*Panulirus penicillatus*) fishery in the eastern coast off Taiwan as an example, we developed an individual-based model (IBM) that is capable of describing the temperature-dependent life history processes and fishery practices of the spiny lobster. We then used the model to evaluate potential impacts of climate changes on the estimation of mortality-based biological reference points for fisheries management. We demonstrate that a warming temperature would increase the yield-per-recruit and egg-per-recruit values, and consequently reduce the risk of overexploitation under the current exploitation level. However, there is a high risk of overexploitation in the long term if higher temperatures also induce extra mortality. An increase in the minimum size regulation (55 mm in carapace length) is proposed as a good candidate measure to reduce the risk of overexploitation for pessimistically unfavorable environmental conditions. This study suggests that an explicit incorporation of the relationships between environmental variables and biological processes can greatly improve fisheries assessment and management.

**29 April, 11:45 (P3-6136)**

## Sustainable fisheries management of Pacific salmon in a warming climate

Masahide **Kaeriyama**, Hyunju Seo and Michio J. Kishi

Faculty of Fisheries Sciences, Hokkaido University, 3-1-1 Minato, Hakodate, Hokkaido, 041-8611, Japan
E-mail: salmon@fish.hokudai.ac.jp

At the present, the global warming has positively affected Hokkaido chum salmon by increasing growth at age-1 and survival. However, in the future global warming may decrease the carrying capacity and the area of suitable habitat for chum salmon in the North Pacific Ocean. To estimate the sustainability of chum salmon to assess seafood security and ocean ecosystem conservation, we pose 3 questions. 1) How can we use the ocean organisms as seafood in the future? 2) What do we need for seafood security and ocean ecosystem sustainability in present and future? 3) How do we establish the sustainable fisheries management based on the ecosystem approach? To answer these issues, we should account for future limitations in ocean carrying capacity and for expected fluctuations in the carrying capacity in response to ecosystem changes. More holistic models are needed that not only address the efficacy of fisheries but also address economic efficiency in the context of the ecosystem. To implement this change, we need paradigm shift from the traditional fisheries science for only fisheries to the ecological fisheries science for the protection of marine ecosystems and human food resources in order to be human well-being in future generation. Adaptive management and the precautionary principle are essential components needed to establish the sustainable fisheries management based on the ecosystem approach.

# Day 4 Plenary Posters

**P3-6376**

## QUEST_Fish: Estimating climate change impacts on global fish production and additional vulnerabilities to human societies

Manuel **Barange**[1], J. Icarus Allen, Eddie Allison, Marie-Caroline Badjeck, Julia L. Blanchard, Ben Drakeford, Nicholas K. Dulvy, James Harle, Jason Holt, Robert Holmes, Simon Jennings, Gorka Merino, Graham M. Pilling and Lynda Rodwell

[1]Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK. E-mail: m.barange@pml.ac.uk or manuel.barange@gmail.com

Climate change is accelerating and is already affecting marine ecosystems and their services. Coupled climate models and ocean observations indicate that the world's oceans are warming and patterns in atmospheric variability are changing, resulting in changes in oceanic stratification, circulation patterns, sea ice and light supply to the surface ocean. Biological responses to these effects are visible but uncertain. The quantification of direct climate impacts on the production of fish resources at the global scale, and the risks and vulnerabilities of these impacts is hampered by many issues. QUEST_Fish is a research project funded by the UK Natural Environment Research Council, and supported by the WorldFish Centre in Malaysia, to address some of these challenges by returning to first principles and focusing on investigating how climate change would affect the potential production for global fisheries resources in the future, compared to past and present scenarios, in the absence of exploitation, and to estimate the added vulnerability of these effects on national, regional and global economies. The project focuses on the added impacts that climate change is likely to cause, and on the subsequent additional risks and vulnerabilities to human societies. The research is anchored on outputs from Global Climate Models and from coupled physical/biological ecosystem dynamic models to predict ecosystem functioning in pre-industrial (1800), present (2005), near future (2050) and future (2100) scenarios. This poster will introduce the methodological multi-disciplinary framework developed by QUEST_Fish to ascertain the impacts of climate change on fish-based socio-ecological systems at different temporal and spatial scales. Specific results of each of the QUEST_Fish workpackages will be presented by members of the team in separate presentations.

**P3-6402**

## Impact assessment of flooding inudation in the Vietnam coastal zone for marine ecosystems by CC and SLR

Du Van **Toan**, Nguyen Van Tien, Vu Thanh Ca, Nguyen Hoang Anh, Nguyen Hai Anh, Vu Thi Hien and Tran The Anh

Department of Marine Resources Management and CC, Research Institute for management of Sea and Islands, Vietnam Administration of Seas and Islands, Ministry of Natural Resources and Environment, 83 Nguyen Chi Thanh Rd., Hanoi, Vietnam
E-mail: duvantoan@gmail.com

This presentation will describe a simulation model for estimating flooding in the coastal regions of Vietnam resulting from Sea Level Rise and Climate Change. Results from simulated flood trajectories for Vinh Quang Commune, Tien Lang district, Hai Phong, derived from storm conditions and the climate change are presented. The simulations are used to assess the impact of flooding on marine ecosystems. Local authorities in the Vinh Quang Commune can use the simulations for land use planning in regions outside the dike and to establish sustainable strategies for use of natural resources while protecting mangroves, and reducing damage caused by climate change and Sea Level Rise in the future.

Scenarios such as climate change and sea level rise associated with storms show that in the Vinh Quang commune region flooding will mainly occur outside the dike area. This region supports aquaculture and mangrove forests and has a high economic value and ecological value. Thus the damage caused by flooding is significant. For example the 2005 Damrey storm caused flooding and damage to shrimp harvest that equated to 0.6 million USD.

**P3-6411 (*Cancelled*)**

## Albacore (*Thunnus alalunga*) distribution versus SST in the Indian Ocean based on 1982-2008 log reports of Taiwaneses longliners

Feng-Chen **Chang**[1] and Shean-Ya Yeh[2]

[1] Overseas Fisheries Development Council, Taipei 106, Taiwan, ROC. E-mail: fengchen@ofdc.org.tw
[2] Institute of Oceanography, National Taiwan University, Taipei 106, Taiwan, ROC

For the last four decades, fishing fleets from Taiwan, Japan, and South Korea have been actively fishing for tunas in the Indian Ocean. Although albacore is one of the major commercially important tunas resources in the Indian Ocean, research endeavors on this species is still not sufficient. Taiwanese catch of Indian albacore fluctuated mainly between 5,000 mt to 26,000 mt, comprising about 60% of the total Indian albacore catch by all fishing countries. As one of the major fishing nations which utilized this resource, it is equally our responsibility to acquire the catch and effort statistics for the purpose of monitoring its status.

It is well-believed that spatio-temporal indicators measured by fishing intensity and physical disturbance are the two major driving forces shaping the distribution of Indian albacore stock. Based on GIS with SST data set and the catch and effort statistics compiled from 1982-2008 Taiwanese log reports of longliners fished in the Indian Ocean, an attempt of applying GAM models with by month and by 5° grid cell of resolutions was carried out mainly for the purpose of elucidating probable correlations between albacore distribution versus fishing activity and SST.

Results so far obtained showed that the effect of SST factor was statistically significant in the GAM modeled in present study. Although albacore seems to appear over rather broad range of SST, the majority of the data showed that it prefers to inhabit in the temperate waters of 14-20°C SST. Further, albacore CPUE indicator appeared an increase trend with concurrent declining CPUE indicators of yellowfin tuna and swordfish resources. More factors, such as fishing operational specifications and geographical pattern of fishing intensity, will be added to the model for further analyses.



**P3-6414**

## An approach to an Integrated Ecosystem Assessment of the Gulf of Mexico

Michael J. **Schirripa**[1], Rebecca J. Allee[2], Russell H. Beard[3], Stephanie Oakes[4], Bonnie J. Ponwith[1], Rebecca Shuford[4] and Roger J. Zimmerman[5]

[1] NOAA, National Marine Fisheries Service, Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL, 33149, USA E-mail: Michael.Schirripa@noaa.gov
[2] NOAA, Gulf Coast Service Center Bldg. 1100, Rm. 232, Stennis Space Center, MS, USA
[3] NOAA, National Oceanographic Data Center, NOAA/NESDIS E/OC1, SSMC3, 4th Floor, 1315 East-West Hwy, Silver Spring, MD, 20910-3282, USA
[4] NOAA, Office of Science and Technology, Marine Ecosystems Divions, 1315 East-West Hwy, Silver Spring, MD, 20910-3282, USA
[5] NOAA, National Marine Fisheries Service, Southeast Fisheries Science Center, 4700 Ave. U, Galveston, TX, 77551, USA

The United States National Oceanic and Atmospheric Administration (NOAA) has recently moved towards an Ecosystem Approach to Management for its eight Large Marine Ecosystems (LME). Towards this end, NOAA is initiating an Integrated Ecosystem Assessment (IEA) effort within the Gulf of Mexico LME, a tropical/sub-tropical, partially isolated body of water that encompasses several international coastlines and a growing human population. An IEA is a synthesis and quantitative analysis of information on relevant physical, chemical, ecological and human processes in relation to specified ecosystem management objectives. The primary goal of our IEA is to unify the critical components of the ecosystem into one integrated model, such as Atlantis or Ecosim-Ecopath, and evaluate trade-offs in resource utilization between the components using a management strategy evaluation framework. We are currently undertaking an IEA for the Gulf of Mexico by laying the groundwork for a single unified data management system which incorporates and combines the catalog and web service functions of EcoWatch and Environmental Research Division's Data Access Program (ERDDAP). Our efforts to date are focusing on creating a sound database structure that will serve as the basis for several individual

IEAs within the overall LME, each addressing specific management questions. IEA management objectives will involve the collection of new data, and rely on making the best use of data that already exists in numerous, distributed databases housed at government agencies, academic institutions, and non-governmental organizations. These distributed data will be discoverable through NOAA's EcoWatch catalog and ERDDAP web services both currently in operation.

# A1 Oral Presentations

### 27 April, 14:35 (A1-6050), Invited

## Examples of using global climate models for regional marine ecosystem projection

Muyin **Wang**[1], James E. Overland[2] and Nicholas A. Bond[1]

[1] Joint Institute for the Study of Atmosphere and Ocean, University of Washington, Seattle, WA, 98195-355672, USA
E-mail: Muyin.wang@noaa.gov
[2] Pacific Marine Environmental Laboratory, NOAA, Seattle, WA, 98115, USA

Climate projections at regional scales are in increased demand from governments, management agencies and other stakeholders. While Atmosphere-Ocean General Circulation Models (AOGCMs) provide credible quantitative estimates of future climate at continental scales and above, the projections at regional scales have larger spread and uncertainty. Individual model performance varies in different regions, on different variables, and for different evaluation metrics. Taking the Arctic, Chukchi Sea, Barents and Bering Seas as examples we demonstrate that the core of the procedure for selecting a useful subset of models for regional projections is a comparative evaluation based on observational constraints at both the continental and regional level. Examples of sea-ice, surface air temperature, sea surface temperature projection for selected regions are used to illustrate the strategy, and the projections will be provided based the selected sub-set models under different emissions scenarios (A2, A1B, and B1). The outputs from these climate models also provide necessary information for regional dynamical/statistical downscaling, which can give quantitative estimate of potential impact of climate change on fish and fisheries. Model evaluation/selection must be an important aspect of the next IPCC report (AR5).

### 27 April, 15:00 (A1-6062), Invited

## Shelf seas ecosystems: Past, present and future states

J. Icarus **Allen**

Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK. E-mail: jia@pml.ac.uk

Shelf seas ecosystems respond to many drivers: climatic forcing impacting on temperature, stratification and circulations, ocean acidification and direct anthropogenic such as nutrient inputs and fishing. The only tools we have to address non-linear combinations of driver impacts in a dynamic environment are numerical simulation models, which include dynamic feedbacks. Because of issues of resolution and process representation, the present the generation of Ocean-Atmosphere-GCMs are a long way off providing credible predictions in coastal/shelf seas, and hence of limited value for informing policy decisions in these regions. Therefore a regional downscaling approach is required. Currently we have the ability to simulate the past and future response of the planktonic shelf seas ecosystems to direct climate drivers and nutrient inputs on regional spatial scales and multi-decadal timescales and use these to drive models of fish stocks; appropriate results will be presented illustrated with examples from the GCOMS, MEECE and QUEST-FISH projects. The following issues are discussed and where; the choice of model structure, scaling processes from physiology to functional types to fish, the ecosystem model sensitivity to changes in the physical environment, new methods for the evaluation and comparison of ecosystem and biogeochemistry models and the quantification of simulation uncertainty.

**27 April, 15:25 (A1-6342)**

## Kuroshio path variation studied by a nested-grid OGCM

Masao **Kurogi**[1], Hiroyasu Hasumi[2] and Yukio Tanaka[1]

[1] Japan Agency for Marine-Earth Science and Technology, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, 236-0001, Japan
[2] Center for Climate System Research, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8568, Japan

It is important to predict the Kuroshio path variation under future climate change since the path strongly affects fisheries. Although an eddy-resolving model is needed for realistic simulation of this variation, a global eddy-resolving ocean model requires a huge amount of computer resources. Instead, we are developing a two-way nested-grid ocean model based on COCO (CCSR Ocean Component Model). This model enables us to realize high performance simulations while using less computational resources. As the first step for this development, an eddy-resolving model around Japan is nested into a North Pacific model and response of Kuroshio path variation is examined relative to changing the amplitude of surface wind forcing. The model is integrated over 30 years with CORE normal year forcing. For normal or 10% weaker wind forcing, both straight and meandering paths alternatively appear. In these cases, path transition is supposed to occur in a multiple equilibrium regime. On the other hand, for 10% stronger wind forcing, only the straight path appears. In this case, the magnitude of current velocity is considered to exceed the range where a stable meandering path can exist.

**27 April, 15:40 (A1-6190)**

## Predicting impacts of climate change on primary production in coastal-ocean regions

Robert **Holmes**[1], James Harle[2], J. Icarus Allen[1], Jason Holt[2] and Manuel Barange[1]

[1] Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK. Email: robe1@pml.ac.uk
[2] Proudman Oceanographic Laboratory, Joseph Proudman Bldg., 6 Brownlow St., Liverpool, L3 5DA, UK

A key challenge in predicting the impact of a changing climate on primary production is the reduction of Ocean General Circulation Model (OGCM) output to scales relevant to coastal marine ecosystems. Computational restraints only allow OGCMs to be run with coarse resolution and, if ecosystem models are used, they tend to be highly simplified. In coastal regions, therefore, mesoscale features are not resolved and processes important to ecosystem function (*e.g.* riverine nutrient input and benthic recycling) are omitted. The QUEST-Fish project addresses this problem by utilising the Global Coastal Ocean Modelling System (GCOMS); a high-resolution, physical/ecosystem model of the world's coastal ocean, based on the established POLCOMS-ERSEM model. GCOMS has grid-spacing of 0.1°, which is eddy-resolving, and many of the processes crucial to shelf sea production are included. The model was run for years 1989-2001 with re-analysis forcing to provide a realistic simulation for comparison with observed data. Four 13-year runs were then completed with forcing from the IPSL-CM4 OGCM. The 4 runs represent pre-industrial, present-day, near-future (2050), and far-future (2100) conditions, with the future conditions based on the SRES A1b "business as usual" emissions scenario. Results and analysis of ecosystem model output from a selection of the QUEST-Fish domains are presented, including estimates of model skill through comparison with satellite data, and analysis of the impact of climate change on primary production predicted by the model.

**27 April, 15:55 (A1-6294)**

## Potential climate change impacts on contrasting shelf sea regions: Atmospheric and oceanic impacts *vs.* tidal and seasonal constraints

Jason **Holt**[1], James Harle[1], Robert Holmes[2] and J. Icarus Allen[2]

[1] Proudman Oceanographic Laboratory, 6 Brownlow St., Liverpool L3 5DA, UK. E-mail: jholt@pol.ac.uk
[2] Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK

We investigate the relative impacts of global climate change on different shelf sea types (*e.g.* Broad tidally mixed, narrow upwelling, in tropical and subpolar zones). The Global Coastal Ocean Modelling System (GCOMS; Holt *et al.*, 2009: *Proc. Roy. Soc. A:*doi:10.1098/rsta.2008.0210.) enables us to simulate any shelf sea region around the world in a consistent and inter-comparable way. GCOMS uses the coupled regional hydrodynamic-ecosystem model POLCOMS-ERSEM, one-way nested in a global ocean general circulation model. With a typical resolution of 7km and 40 vertical (terrain following) levels, GCOMS provides an effective tool for dynamical downscaling of

climate change simulations to investigate impacts in shelf sea/coastal regions. In stimulations run for the QUEST-FISH project, GCOMS is forced by a coupled ocean-atmosphere GCM (IPSL-CM4, with the SRESA1B emissions scenario). We investigate the hypothesis that shelf seas where comparatively stable astronomical cycles dominate (specifically seasonal and tidal cycles) experience climate change impacts in a quantitatively and qualitatively different fashion to those where other oceanic/atmospheric influences dominate. We focus on stratification, mixed layer depth and ocean-shelf coupling, and consequent nutrient resupply and primary production. Climate change stimulations are guided by reanalysis forced stimulations and contemporary ocean data sets. Twelve regions are considered, which cover twenty Large Marine Ecosystems that account for more the 60% of the global fish catch. Results from these simulations are used in other components of QUEST-FISH to drive dynamic models of community size spectra to estimate the impacts of climate change on the potential for fish production in the absence of exploitation.

**27 April, 16:30 (A1-6107)**

## Downscaling climate simulations in the North Pacific Ocean using a fully coupled multi-scale model

Enrique N. **Curchitser**[1], William Large[2], Kate Hedström[3] and Jon Wolf[2]

[1] Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ, 08901, USA
E-mail: enrique@marine.rutgers.edu
[2] National Center for Atmospheric Research, 1850 Table Mesa Dr., Boulder, CO, 80305, USA
[3] Arctic Region Supercomputing Center, University of Alaska Fairbanks, 909 Koyukuk Dr., Suite 105, Fairbanks, AK, 99775, USA

As the models used for the IPCC assessments keep evolving, interest is rising in the impacts of climate change on regional scales. Because of the substantial cost of running existing climate models, critical processes, such as mesoscale eddy induced variability and coastal upwelling are either parameterized, or simply not resolved. There are several studies using one-way downscaling of climate models to particular regions, though those studies do not permit important feedbacks in the climate system, limiting their use for future projections. In this paper we present a fully coupled multi-scale climate model based on the NCAR CCSM global model and the ROMS regional ocean model. We will show that features, such as coastal upwelling, produced by the higher-resolution model have significant impacts on the global climate system.

**27 April, 16:45 (A1-6293)**

## Dynamical downscaling from the basin scale to submesoscale with a triply nested ocean model

Hiroshi **Kuroda**, Takashi Setou, Manabu Shimizu and Kazuhiro Aoki

National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Kanagawa, 236-8648, Japan
E-mail: kurocan@affrc.go.jp

To study the interactions of fisheries biology between open-ocean and continental shelf waters, we have developed a triply nested ocean model based on the Regional Ocean Model System (ROMS). This strategy is essential to simulate the shelf circulation around Japan, where the shelf width is sufficiently narrow (<50km) for the offshore oceanic disturbances to seriously affect the shelf water. In this presentation we introduce our downscaling system and discuss several problems for the application of this system to the global-warming state. Our system consists of a 1/2-degree eddy-permitting model covering the whole of the North Pacific, a 1/10-degree eddy-resolving model around Japan, and a 1/50-degree shelf model targeting the inshore part of the Kuroshio. These models are connected by one-way nesting techniques and are presently driven by climatological monthly mean forcings under the non-global warming state. It is confirmed that the 1/2-, 1/10- and 1/50-degree models can successfully reproduce typical basin-scale, mesoscale, and submesoscale variabilities in the ocean, respectively. Particularly focusing on the submesoscale variability simulated by the triply nested 1/50-degree model, we can recognize several interactions between the northern front of the Kuroshio and irregular topography south of Japan. It is shown that the Kuroshio frontal disturbance is generated mainly near the cusp (*i.e.*, the tip of a cape), and propagates as a frontal wave to the downstream region along the coast. A crest of the frontal waves then encounters the subsequent cusp in the downstream region, so that warm oceanic water spreads intermittently over the shelf region.

**27 April, 17:00 (A1-6038)**

## Climatic structural stability of the Kuroshio Extension jet and catastrophe theory

Talgat R. **Kilmatov**[1,2] and Elena V. Dmitrieva[2]

[1] Pacific State University of Economics (PSUE), 19 Okeansky St., Vladivostok, 690091, Russia. E-mail: talgat_k@mail.ru
[2] V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, 43 Baltiyskaya St., Vladivostok, 690041, Russia
E-mail: e_dmitrieva@poi.dvo.ru

The slow accumulation of thermodynamic parameters owing to climatic trends can cause a fast structural instability of ocean structures. The application of catastrophe theory to research the instability of the ocean jet currents is shown. The conservation energy equations applicable to a zonal jet current are constructed where the jet width is a local control parameter. An analysis of the equations shows that a bifurcation is created owing to the gradient reduction of the water density across the current. The direct variational method based on minimum entropy production as applied to an ocean jet current is shown. The model shows that the cross-jet difference in water density is the important determining parameter on the existence of the jet current. There is a critical cross gradient in density when the current is not a jet current anymore. Using the HadSST data set for the North Pacific, the time variability of the non-uniformity temperature for the last 60 years (1948-2007) is analysed. The temperature of the subarctic zone increases more than the SST in the subtropical zone as a result of climatic changes. A rough comparison of the SST climatic trends and energy and variational modeling shows that it is possible to destroy the structure of the Kuroshio Extension as a jet current as the north-south difference between the subarctic – subtopic water temperatures (densities) is decreased.

**27 April, 17:15 (A1-6375)**

## Simulated modes of biophysical variability on the Bering Sea shelf

Albert J. **Hermann**[1], Kerim Aydin[2], Nicholas A. Bond[1], Wei Cheng[1], Enrique N. Curchitser[3], Georgina A. Gibson[4], Kate Hedström[5], Ivonne Ortiz[2], Muyin Wang[1] and Phyllis J. Stabeno[6]

[1] Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA, 98195, USA
E-mail: albert.j.hermann@noaa.gov
[2] Alaska Fisheries Science Center, NOAA/NMFS, Seattle, WA, 98195, USA
[3] Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ, 08901, USA
[4] International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, AK, 99775, USA
[5] Arctic Region Supercomputing Center, Fairbanks, AK, 99775, USA
[6] Ocean Environment Research Division, NOAA/PMEL, Seattle, WA, 98195, USA

The continental shelf of the Bering Sea is one of the most productive regions of the global ocean. One major element of the Bering Ecosystem Study/Bering Sea Integrated Ecosystem Research Program (BEST-BSIERP) entails the downscaling of IPCC projections of global climate change to the regional physics and biology of the Bering Sea. These regional projections are derived using coupled physical, nutrient-phytoplankton-zooplankton (NPZ), and fish models, to better capture the nonlinear effects of climate change as they cascade among the trophic levels of the ecosystem. Our 3D hydrodynamic model is based on the Regional Ocean Modeling System (ROMS), and includes both ice and tides. The embedded NPZ model includes multiple size classes of phytoplankton and zooplankton, as well as significant fish prey such as euphausiids. The higher tropic level model (FEAST) includes ~50 length classes each of pollock, cod, and arrowtooth flounder, with allometric relationships connecting fish size to food preference. Strong coupling among these models ensures the inclusion of both bottom-up and top-down effects in restructuring the ecosystem. Of special interest are the emergent properties of these coupled simulations, and how they compare with the observed system. In this presentation we use Empirical Orthogonal Functions to examine the covariance structure of predicted physical-biological modes from the coupled models, with a particular emphasis on pelagic *vs.* benthic food webs on the Bering Sea shelf, and their dependence on ice cover.

**27 April, 17:30 (A1-6264)**

## Tidal current effects on the simulation of ocean circulation by theoretical and numerical analyses

Huaming **Yu**[1,2], Thomas Pohlmann[2], Xianwen Bao[1] and Xueen Chen[1]

[1] College of Physical and Environmental Oceanography, Ocean University of China, Songling Rd. 238, Qingdao, 266100, PR China. E-mail: huamingyu@gmail.com

[2] Institute of Oceanography, Centre for Marine and Atmospheric Sciences, University of Hamburg, Bundesstr. 53, Hamburg, 20146, Germany

Ocean circulation plays an important role in the climate system and its accuracy is a prerequisite for accurately forecasting the climate. In addition, the ubiquitously existing tidal currents in the global ocean interact intensively with the ocean circulation, especially in the marginal seas where tidal residual currents are significant. However, neither present-day ocean circulation nor tidal models have taken these interactions into account, rather treating them separately, due to their temporal and spatial scale differences. In this work, mechanisms of the interaction between tidal current and ocean circulation are analyzed theoretically by deriving the mechanical energy equation from the original momentum equations with tide-generating forcing. Furthermore, estimates of the mean winter circulation are obtained by a three-dimensional nonlinear numerical finite volume Global Ocean Circulation and Tide Model (GOCTM), which has attained high spatial resolution in the East China Sea using unstructured grids. The effects of the tides, stratification and wind are taken into account in the simulations. And quantitative estimates of the contributions of these three dominant components to the circulation are provided through a number of systematic numerical experiments. Estimates of nonlinear interactions, including those arising from the advection term and dispersion term, between tidal currents and circulation are also derived from an energy aspect. The analysis results show that tides appear to be the dominant mechanism that causes nonlinear interactions between the flow components. The work is inspiring ideas to create tidal parametric schemes for ocean circulation models.

**27 April, 17:45 (A1-6017)**

## The Black Sea zooplankton-climate connection: A multi-scale approach and new methods

Alexandra V. **Temnykh**, Yuriy N. Tokarev and Viktor V. Melnikov

Institute of Biology of the Southern Seas, NAS of Ukraine, 2, Nakhimov Ave., Sevastopol, Ukraine. E-mail: atemnykh@rambler.ru

Existing paradigm of the Black Sea zooplankton changes is based on essential simplification of properties of the biological components: all changes are explained mainly by influence of new invaders. As a result of this simplification, the main essence of climatic changes occurring in the Black Sea ecosystem is often lost. In order to overcome this problem we show that it is necessary to examine multiscale processes at the different levels that they influence distribution and species - size structure of zooplankton. Some examples are the influence of wind, Langmuir circulations, Upper Isothermal Layer development, Cold Intermediate Layer development and the dynamics of the vertical position of the lower boundary of zooplankton habitat. It is shown, that structure of the water mass can determine habitat conditions for the cold water species of zooplankton in the Black Sea. A new multi-net Cassette Planktonometer was designed to assist research into these processes. The device can collect 10 zoo- and ichthyoplankton samples within thin layers using horizontal, sine or oblique tows and has the capability of taking successive samples. Preliminary research results are described.

**27 April, 18:00 (A1-6069)**

## Toward a regional climate model for the British Columbia continental shelf

Michael **Foreman**[1], Badal Pal[2], William Merryfield[2], Diane Masson[1] and John Morrison[1]

[1] Institute of Ocean Sciences, Fisheries and Oceans Canada, P.O. Box 6000, Sidney, BC, V8L 4B2, Canada
E-mail: mike.foreman@dfo-mpo.gc.ca

[2] Canadian Centre for Climate Modelling and Analysis, Environment Canada, University of Victoria, P.O. Box 3065 Stn CSC, Victoria, BC, V8W 3V6, Canada

Though statistical downscaling has been widely used to interpolate results from global climate models to specific oceanic locations, the resultant fields can be inaccurate if those models are unable to represent important meso-scale features and processes. This is certainly the case for the waters off British Columbia where mountainous terrain and complicated coastlines and bathymetry combine with seasonally varying winds to produce sub-regions that have high biological productivity in the summer and that export larvae and nutrients offshore in the winter. In order to better understand how these processes may change in the future, a regional climate model is being developed for the continental shelf waters off British Columbia. This model will initially take its atmospheric forcing from one or more regional, atmosphere-only, climate models (either the Canadian Regional Climate Model or the University of Washington regional climate model) and have its coastal freshwater discharges estimated from downscaled precipitation and watershed models. Initial and lateral boundary conditions for salinity and temperature will be computed as downscaled anomalies from global models. In this presentation, we will describe progress in the development of this model with particular attention given to analyses of the winds that will be used to force it.

**27 April, 18:15 (A1-6393)**

## Evaluation of potential limitations for statistical downscaling in the Far-Eastern Seas

Elena I. **Ustinova**

Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), 4 Shevchenko Alley, Vladivostok, 690950, Russia
E-mail: eustinova@mail.ru

In this study several potential limitations for statistical downscaling in the Far-Eastern Seas, such as data problems, specifying "sub-grid" physical processes and instabilities in the relationships between the regional characteristics and large-scale parameters, are analyzed. Although multi-year data on ice cover, air and water temperature from meteorological stations are the longest time series of relatively regular and homogeneous information for the Seas, the number of observations is still short. Moreover, assessing the changes in large-scale atmospheric patterns and their relationships to regional conditions in the Far-Eastern Seas remains a difficult task owing to the coarseness of the meteorological station network along the Russian continental coast, even for a standard variable such as air temperature. Whereas statistical downscaling assumes that the relationships between predictors (large-scale variables) and predictands (small-scale variables) do not vary under climate change conditions, the relationships between regional characteristics (mainly sea ice coverage, air and water temperature in the Far-Eastern Seas) and large-scale climatic indices are unstable in a number of cases. In addition, the quasi-steady state nature of the climatic system (from one regime shift to other) can be broken locally in the Far-Eastern Seas because of moving climatic atmospheric and oceanic fronts, trajectories of cyclones and other boundary phenomena connected with geographical position of the Seas. The method of atmospheric circulation typing (for example, created by Glebova for Far-Eastern Seas in 1999) allows one to decrease some limitations in these regression models. However, this method requires the additional task of classifying.

# A1 Poster

**A1-6347**

## Downscaling global climate predictions for the North Sea - A discussion about quality

Anne D. Sandvik, Solfrid Sætre **Hjøllo** and Anne Britt Sandø

Institute of Marine Research, P.O. Box 1870 Nordnes, Bergen, 5817, Norway. E-mail: anne.sandvik@imr.no

The North Sea is a shallow shelf sea situated between Norway, the British Isles and the European continent, where bottom-up forcing of the marine ecosystems has been shown to be important. It is therefore of crucial importance to have a high quality representation of the physical environment and its variability for all marine climate effect studies. It is well known that there can be both huge seasonal and substantial inter-annual variations as well as long term oscillations with modest amplitudes. The consensus about the mean global features expected in the 21th century is summarized in the 4th assessment report from IPCC, but for high resolution, future climate estimates of hydrography and currents, coarse scale global climate predictions need to be downscaled. Since the uncertainty in all climate predictions are unknown and the uncertainty is assumed to increase from the global to the regional scale, a comparative study between existing regional downscaling of selected GCMs has been performed to ensure high quality data for further downscaling. For the lateral boundary conditions, datasets from the control runs of three global coupled models (the BCM, the GISS AOM and the NCAR CCSM3.0.) which have been downscaled using the ROMS model, are analyzed to find the best downscaled dataset for our purposes. The focus will be on North Sea variability and extreme years.

# A2 Oral Presentations: Day 1, April 26

**26 April, 14:35 (A2-6085), Invited**

## Oxygen- and capacity-limitation of thermal tolerance: A matrix for integrating climate-related stressor effects in marine ecosystems

Hans-O. **Pörtner**

Integrative Ecophysiology, Alfred-Wegener Institute, Am Handelshafen 12, Bremerhaven, 27570, Germany
E-mail: Hans.Poertner@awi.de

The concept of oxygen and capacity dependent thermal tolerance in aquatic ectotherms has successfully explained climate-induced effects of rising temperatures on species abundance in the field. Oxygen supply to tissues and the resulting aerobic performance characters thus form a primary link between organismal fitness and its role and functioning at ecosystem level. The thermal window of performance in water breathers matches their window of aerobic scope. Loss of performance reflects the earliest level of thermal stress, caused by hypoxemia and the progressive mismatch of oxygen supply and demand at the borders of the thermal envelope. Oxygen deficiency elicits transition to passive tolerance and associated systemic and cellular stress signals like hormonal responses or oxidative stress as well as the use of protection mechanisms like heat shock proteins at thermal extremes. Thermal acclimatization between seasons or adaptation to a climate regime involves shifting thermal windows and adjusting window widths. The need to specialize on a limited temperature range results from temperature dependent trade-offs at several hierarchical levels, from molecular structure to whole organism functioning and may also support maximized energy efficiency. Various environmental factors like $CO_2$ (ocean acidification) or hypoxia interact with these principal relationships. Existing knowledge suggests that these factors elicit metabolic depression supporting passive tolerance to thermal extremes. However, they also exacerbate hypoxemia causing a narrowing of thermal performance windows and leading the organism earlier to the limits of its thermal acclimation capacity. The conceptual analysis suggests that the relationships between energy turnover, the capacities of activity and other functions and the width of thermal windows may lead to an integrative understanding of specialization on climate and, as a thermal matrix, of sensitivity to climate change and the factors involved. Such functional relationships might also relate to climate-induced changes in species interactions and thus, community responses at the ecosystem level.

**26 April, 15:00 (A2-6099), Invited**

## Climate effects on maturation and spawning of Atlantic cod and implications for fisheries

Olav Sigurd **Kjesbu**[1], Jon Egil Skjæraasen[2], David Righton[3], Kathrine Michalsen[1], Christian Jørgensen[2], Anders Frugård Opdal[2] and Peter R. Witthames[4]

[1] Institute of Marine Research, P.O. Box 1870, Bergen, N-5817, Norway. E-mail: olav.kjesbu@imr.no
[2] Department of Biology, University of Bergen, N-5020, Norway
[3] Centre for Environment Fisheries and Aquaculture Science, Pakefield Rd., Lowestoft, Suffolk, NR330HT, UK
[4] Fecund Fish Consultancy, 40 Plumtrees, Lowestoft, Suffolk, NR32 3JH, UK

The timing and success of spawning in marine fish is of fundamental importance to population persistence, distribution and, for commercial species, sustainability. Their physiological processes of reproduction are regulated, in part, by water temperature, and therefore changes in marine climate may have dramatic effects upon spawning performance. Using adult Atlantic cod (*Gadus morhua*) as a case study, we examined the links between water temperature, body size, vitellogenesis and spawning time by conducting extensive laboratory and field studies. Our experiments documented that vitellogenesis generally starts at the autumnal equinox, and that oocyte growth and investment is greater in cod held at warmer temperatures. Furthermore, spawning occurred earlier when oocyte growth was more rapid. Large females spawned earlier than smaller females at warmer temperature but this effect vanished at colder temperature. The experimental results were confirmed by measurements of oocyte growth collected from wild caught cod in northern (Barents Sea) and southern (Irish and North Seas)

populations. A model of oocyte maturation was successfully developed to explain the results. This model was consistent with published egg production curves of cod from the Barents Sea, North and Irish Seas, considering *in situ* temperatures recorded by individual data-storage tags on cod in those areas. These findings have considerable relevance for future studies of fish recruitment in relation to climate change and applied harvesting strategies on spawning populations.

**26 April, 15:15 (A2-6153)**

## An experimental assessment of effects of raised $pCO_2$ on early-larval Antarctic krill

So **Kawaguchi**[1], Haruko Kurihara[2], Robert King[1], Lillian Hale[3], Thomas Berli[3], James Robinson[3], Patti Virtue[3], Stephen Nicol[1] and Atsushi Ishimatsu[4]

[1] Australian Antarctic Division, Kinsgston, TAS, 7050, Australia. E-mail: So.Kawaguchi@aad.gov.au
[2] University of Ryukyus, Okinawa, 903-0213, Japan
[3] University of Tasmania, Sandy Bay, TAS, 7005, Australia
[4] Nagasaki University, Nagasaki, 851-2213, Japan

The Southern Ocean is thought to be one of the earliest marine ecosystems to be affected by ocean acidification because of the higher solubility of $CO_2$ in colder waters and the upwelling of high $CO_2$ deep seawater. Most studies on the effects of $CO_2$ and acidification to date concern aragonite shell forming species (*e.g.* epi-pelagic planktonic pteropod molluscs, foraminifera, some benthic invertebrates). Antarctic krill is known as the keystone species of the Southern Ocean ecosystem and represents the largest fishery species in the Southern Ocean and the economic interest in krill continues to increase. However, despite the importance of krill, the effect of elevated $CO_2$ on this species has never been investigated. Our preliminary experimental assessment of raised $pCO_2$ on early-larval krill was unable to detect any significant effects up to 1000matm, but did reveal detrimental impact at 2000 matm $pCO_2$. Krill display extensive ontogenetic vertical migration during their early larval stage down to ~1000m depth where seawater $pCO_2$ is already similar to or above the projected atmospheric $pCO_2$ for year 2100 (A1FI scenario). Krill in early larval stages are perhaps well adapted to the $pCO_2$ range they experience during development, but highly sensitive to higher levels. We believe this finding stands as an important recommendation for the use of projected $pCO_2$ levels prevailing in organisms' habitat depth according to the phases of their life history rather than simply adopting future atmospheric values, in order to better predict $CO_2$ impacts on vertically migrating species such as krill.

**26 April, 15:30 (A2-6090)**

## Fish production in coastal habitats under global warming: Spatio-temporal variability in early growth of a dominant species, black rockfish, in seagrass beds

Jun **Shoji**, Masakazu Hori, Yasuhiro Kamimura, Ken-ichiro Mizuno and Shun-ichi Toshito

Takehara Fisheries Research Laboratory, Hiroshima University, 5-8-1 Minato-machi, Takehra, Hiroshima 725-0024, Japan
E-mail: jshoji@hiroshima-u.ac.jp

Seagrass beds have been considered to produce almost the highest values of annual ecosystem services among the world's ecosystems. Black rockfish *Sebastes inermis* is one of the most dominant components of the fish fauna within seagrass beds in temperate waters of the western North Pacific. Larval and juvenile rockfish immigrate into seagrass beds in early March at a total length of about 20 mm and reach to 80 mm in summer. In order to estimate the possible effects of global warming on fish production within seagrass beds, growth of larval and juvenile rockfish was examined at a variety of temperatures both under laboratory and natural conditions. Otoliths of wild-caught larvae and juveniles were processed for estimation of cohort-specific growth ($G$) and mortality ($M$) coefficients and for back-calculation of growth trajectories of individual fish. Under laboratory conditions, effects of temperatures on growth, gastric evacuation rate and daily ration during the post-settlement period were examined at 10-20°C. Mean growth rate of the larval and juvenile rockfish was highest at about 14°C. Daily ration was about 20% body weight at all temperatures tested and the net growth efficiency was highest at 16°C. Based on the possible increase in water temperature (2 to 3°C by 2095), it is plausible to expect a reduction in juvenile fish production within the coastal habitats and/or a northward shift in the distribution of rockfish. Preliminary analysis of possible growth impacts of reduced photoperiod that larval and juvenile rockfish would experience at higher latitudes was also conducted.

**26 April, 15:45 (A2-6020)**

## The Mediterranean Sea as a trap for endemic fishes facing climate change

Frida **Ben Rais Lasram**[1], Francois Guilhaumon[2], Samuel Somot[3], Wilfried Thuiller[4] and David Mouillot[2]

1 Laboratoire Ecosystèmes et Ressources Aquatiques UR03AGRO1, Institut National Agronomique de Tunisie, 43 Ave. Charles Nicolle, 1082 Tunis, Tunisia. E-mail: frida.lasram@gmail.com
2 Laboratoire Ecosystèmes Lagunaires UMR 5119, Université Montpellier 2, cc 093, Place E. Bataillon, 34095 Montpellier Cedex 5, France
3 Météo-France, Centre National de Recherches Météorologiques, 42 Ave. Gaspard Coriolis, 31057, Toulouse Cedex, France
4 Laboratoire Ecologie Alpine, UMR 5553, Université J. Fourier, BP 53, 38041 Grenoble Cedex 9, France

The Mediterranean Sea is a hotspot of biodiversity where endemic fish species are expected to be significantly influenced by climate change. However, predictions of geographical range extensions or contractions have not yet been thoroughly investigated. Here, we projected the potential future climatic niches of 75 Mediterranean endemic fish species based on a climate change scenario implemented using the Mediterranean model OPAMED8 and a multi-model inference including uncertainty. Model results indicated that low prevalence species inhabiting cold waters were the first to undergo a high probability of extinction by the middle of the 21st century followed by high prevalence species by the end of the century. In species that declined, projections for 2041-2060 revealed that 75% would be classified on the IUCN Red List while 20% were projected to become extinct. For 2070-2099, the IUCN Red List was expected to contain 90% of species with a reduced geographic range, out of which 33% were projected to be extinct. By the middle of the century, the coldest areas of the Mediterranean (Adriatic Sea and Gulf of Lion) would act as a refuge for cold-water species but, by the end of the century, such areas would act as a trap, driving them towards extinction. In contrast, thermophilic species were projected to colonize new areas. As a result, high rates of species turnover were expected. Marine protected areas may mitigate the speed of this turnover (by reducing fishing pressure) however, the consequences of changes in species assemblages on ecosystem functioning remain challenging to predict.

**26 April, 16:20 (A2-6362), Invited**

## How has climate change impacted marine food-webs in the past, and how might we predict changes in the future?

John K. **Pinnegar**[1], Georg Engelhard[1], Julia L. Blanchard[1], Joe Scutt-Phillips[1] and William L. Cheung[2]

1 Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Pakefield Rd., Lowestoft, Suffolk, NR33 0HT, UK
E-mail: john.pinnegar@cefas.co.uk
2 School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK

Aquatic food-webs can be incredibly complex and dynamic, with species interactions occurring at a range of temporal and spatial scales, from fleeting transient predation events to large-scale, multi-trophic level cascade effects. Different species tend to react to climate change in different ways, with climate affecting growth, reproductive success, mortality, spatial distribution, *etc.* Consequently it can be very difficult to predict how a food-web might look in the future.

In this talk we describe changes that have occurred in the NE Atlantic ecosystem over the past 100 years, and we attempt to discern whether or not these changes have been driven primarily by long-term climate variability or by other factors such as intensive fishing pressure and/or habitat modification. We demonstrate substantial shifts in the distribution of key commercial fish stocks in the North Sea, as well as changes in food-webs, as indicated by a 100 year time series of fish diet data. We consider how predator-prey overlap may have changed over the past 30 years, and how such changes might continue in the future, as a consequence of climate change and shifting species distribution patterns. We discuss techniques that are available to try to predict indirect food-web implications of climate change. These techniques are applied to a number of different case-study regions in northern Europe and in southern Africa.

**26 April, 16:45 (A2-6109)**

## The effects of fish life histories on time scales of response to environmental change

Louis W. **Botsford**[1], Matthew D. Holland[2], Alan Hastings, Michael J. Fogarty[3], Francis Juanes[4] and Hui-Yu Wang[4]

[1] Department of Wildlife, Fish and Conservation Biology, University of California, Davis, CA, USA. E-mail: lwbotsford@ucdavis.edu
[2] Department of Environmental Science and Policy, University of California, Davis, CA, USA
[3] National Marine Fisheries Service, Woods Hole, MA, USA
[4] Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA, USA

The responses of age-structured fish populations to changes in their environment depend on age-dependent vital rates and characteristics of density-dependent recruitment, in addition to the environmental signals. Here we describe those responses in terms of (1) population sensitivities to different time scales of environmental variability and (2) the potential for population collapse. Population sensitivity to various time scales differs depending on whether the environment affects survival or development rates. Fishing and long-term declines in survival precondition populations to greater variability. The time scales of population variability also depend on the specific population observation (*e.g.*, whether recruitment or abundance). Understanding the basis for these responses will be useful in projecting the effects of projected changes in the physical environment. We will illustrate these differences with examples from cod and salmon.

**26 April, 17:00 (A2-6080)**

## Disentangling the effects of fisheries and climate change on fish communities

Remment **ter Hofstede** and Adriaan D. Rijnsdorp

IMARES (Institute for Marine Resources and Ecosystem Studies), P.O. Box 68, 1970 AB IJmuiden, The Netherlands
E-mail: remment.terhofstede@wur.nl

Fish communities are dynamic and their structure is known to change over time. Traditionally these changes were considered to be fisheries-induced, but recently global warming is often suggested to affect the distribution, abundance, and assemblage composition of fish. However, to disentangle the effects caused by either fisheries or climate change seems to be close to impossible since both aspects in general occur at the same time. In our study we separate fisheries effects from climate change by comparing survey catch data from the southern North Sea during periods, characterised by i) low fishing effort during a cold period (1903-1909), ii) low fishing effort during a warm period (1950-1956), iii) high fishing effort during a cold period (1977-1983), and iv) high fishing pressure during a warm period (2002-2008).

We hypothesize that species richness of fish is higher during warm periods than cold periods due to an increase in Lusitanian (warm-favouring) species, and lower during periods of high fishing pressure due to a decrease in large (targeted) Boreal species.

**26 April, 17:15 (A2-6145)**

## Comparative study of fishing-induced juvenescence effects under different climatic and fishing harvesting scenarios

Manuel **Hidalgo**[1], Valerio Bartolino[2], Santiago Cerviño[3], Angélique Jadaud[4], Enric Massutí[5], Fran Saborido-Rey[6], Marina Santurtún[7] and Nils Christian Stenseth[1]

1 Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biology, University of Olso, P.O. Box 1066, Blindern, Oslo, 0316, Norway. E-mail: manuel.hidalgo@bio.uio.no
2 Department of Animal and Human Biology, University of Rome "La Sapienza", 32 Viale dell'Universita, Rome, 00185, Italy
3 Instituto Español de Oceanografía Centro, Oceanográfico de Vigo, Cabo Estai - Canido s/n 36200, Vigo, Spain
4 IFREMER - Centre Halieutique Méditerranéen et Tropical, Laboratoire de Ressources Halieutiques, Bd Jean Monnet, B.P. 171, 34203 Sète Cedex, France
5 Instituto Español de Oceanografía, Centre Oceanografic de Balears, Moll de Ponent s/n, 07015 Palma de Mallorca, Spain
6 Institute of Marine Research (CSIC), 6 Eduardo Cabello, Vigo, 36208, Spain
7 AZTI Tecnalia, Resource Department, Txatxarramendi Ugartea Z/G, Sukarieta (Bizkaia), España

The age truncated or juvenescent populations are a worldwide consequence of the protracted size-selective mortality of commercial fishing on the older and larger individuals. This process increases a populations' ability to directly respond to environmental fluctuations, emphasizing the importance of the interaction between fisheries, environment and internal dynamics that produces complex synergic effects on the population dynamics of marine species. However, the output of this complex interplay is often species- and context-dependent. In this study, we use a species-specific case of study (European hake, EH, *M. merluccius*) to investigate how ecological consequences of fisheries-induced juvenescent on individual traits (*e.g.*, size at maturation, mean length-at-age) and population properties (*e.g.*, intrinsic growth rate) interacted differently with one another depending on the environmental and fishery harvesting scenario. We used a comparative approach investigating five stocks of EH, two from the Atlantic and three from the Mediterranean Sea. Although the Mediterranean is a more oligotrophic system compared with the Atlantic, different oceanographic-productive conditions existed at smaller spatial scales within each of these main areas. Additionally, compared to Atlantic fisheries, those in the Mediterranean harvest relatively more juveniles. By combining all sources of information, we investigate differences in the coupling between life history traits and population dynamics for all stocks that display different level of juvenescence. This study will advance our understanding of the underlying mechanisms behind the transitory relationships between climate and fish populations.

**26 April, 17:30 (A2-6034)**

## Bringing together molecular genetics and population dynamics modelling: Disentangling the influence of fisheries and climate variation in the endangered European eel

J. Marti **Pujolar**[1], D. Bevacqua[2], M. Andrello[3] and L. Zane[1]

1 Dipartimento di Biologia, Università di Padova, Via G. Colombo 3, Padova, I-35131, Italy. E-mail: josemartin.pujolar@unipd.it
2 Dipartimento di Scienze Ambientali, Università degli Studi di Parma, Parco Area delle Scienze 11A, Parma, I-43100, Italy
3 Laboratoire d'Ecologie Alpine (LECA), CNRS UMR 5553, Grenoble, 38041, France

The stock of the European eel has shown a dramatic decline over the last decades and is considered to be outside safe biological limits, with a drop of 90-99% in recruitment and 75% in adult landings in the last 30 years. Causes of the crash include anthropogenic factors such as overfishing and climate-driven changes in environmental factors such as ocean currents. The goal of the present study was to achieve a comprehensive understanding of the role of demographic processes that determine the population structure of the European eel using a European eel-specific genetic-demographic model that takes into account the complex life cycle of the species which includes movement between the spawning ground in the Sargasso Sea and the feeding grounds in continental Europe. The main result of the study is the observation of a pattern of genetic patchiness (highly significant differentiation without a temporal or geographic pattern), which was only mimicked in the model when reproduction in the Sargasso Sea occurred in a small number of spawning events isolated from each other in time and/or space, with an average of 130 breeders in each spawning event. The discrepancy between migrating adults (30 millions per year) and actual breeders is thought to be due to unpredictable oceanic conditions causing reproductive failure in a significant fraction of individuals. A low effective population size combined with increase climate-variability during the last decades might have contributed to the current decline in abundance of the European eel.

**26 April, 17:45 (A2-6115)**

## Response of yellowtail *Seriola quinqueradiata* in the Japan Sea to sea water temperature over the last century and potential effect of global warming

Yongjun **Tian**[1], Hideaki Kidokoro[1], Tatsuro Watanabe[1], Yosuke Igeta[1], Hideo Sakaji[2] and Ken Watanabe[3]

[1] Japan Sea National Fisheries Research Institute, Fisheries Research Agency (FRA), Suidou-cho, 1 Niigata, 951-8121, Japan
E-mail: yjtian@fra.affrc.go.jp
[2] National Research Institute of Fisheries Science, Research Agency (FRA), 2-12-4 Fukuura, Kanazawa, Yokohama, 236-8468, Japan
[3] Toyama Prefectural Fisheries Research Institute, 364 Takatsuka, Namerikawa, Toyama, 936-8536, Japan

The yellowtail *Seriola quinqueradiata* is one of the most important, large-predatory fishes in Japanese waters. Using the historical catch data of yellowtail and a sea surface temperature (SST) data set for the waters around Japan over the last century, the long-term variability in the abundance of yellowtail and its relation with SST was examined. The total catch of yellowtail increased from 14,446 tons in 1894 to 77,462 tons in 2000 with an evident increasing trend over the last century. However, the trend is not linear but decadal with significant shifts occurring around in 1911, 1931, 1950, 1973 and 1989, strongly suggesting an effect of water temperature. Analysis of the catch in various fisheries regions and SSTs showed that the catch trend was approximately in accordance with SSTs. In particular, the catch from the Japan Sea was significantly and positively correlated with winter SST in the northern Japan Sea, indicated the increasing water temperature in the Tsushima Current region has a positive effect on the migration and recruitment of yellowtail to the Japan Sea. SST maps indicated a northward movement in distribution and overwintering areas of yellowtail in the Japan Sea in 1990s that corresponded to increased SST. These results suggest that migration pattern, distribution and overwatering area are largely dictated by SST. Hence, the potential impacts of global warming on migration, distribution and fisheries grounds of yellowtail in the Japan Sea were estimated under the prediction scenario A1B of IPCC, indicating northward expansions in distribution and over-wintering region, and large changes in the current fishing grounds.

**26 April, 18:00 (A2-6258)**

## Key mechanism determining the impact of climate change on the productivity and fisheries of North Sea plaice, *Pleuronectes platessa* L.

Adriaan D. Rijnsdorp[1], Ralf **van Hal**[1], Marc Hufnagl[2], Richard D.M. Nash[3], Alexander Schroeder[4], Lorna R. Teal[1], Ingrid Tulp[1], Rob Witbaard[1,5], Doug Beare[1] and Henk W. van der Veer[5]

[1] Wageningen IMARES, P.O. Box 68, 1970 AB IJmuiden, The Netherlands. E-mail: adriaan.rijnsdorp@wur.nl
[2] Centre for Marine and Climate Research, Institute of Hydrobiology and Fisheries Science, University of Hamburg, Olbersweg 24, Hamburg, D-22767, Germany
[3] Institute of Marine Research, P.O. Box 1870, Nordnes, Bergen, N-5817, Norway
[4] Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, D-27570, Germany
[5] Royal Netherlands Institute for Sea Research, P.O. Box 58, 1790 AB Den Burg, Texel, The Netherlands

Climate change will impact both habitat quality and connectivity between spawning and nursery grounds. The possibility of reaching nursery habitat and the quality of this nursery habitat are key factors determining population size in flatfish such as plaice. Coinciding with the recent warming, juveniles have moved to deeper offshore water, suggesting a deterioration of the quality of nursery habitat. We analysed the effects of recent climate variability on habitat quality and connectivity, using survey data and bio-physical modeling. The distribution shift of juveniles to offshore waters is not solely due to an avoidance response to high summer temperature, but to the combined effect of the increase in temperature and a decrease in food availability. Climate-induced changes in connectivity and nursery habitat quality caused changes in the size and location of suitable spawning habitats. Climate change is expected to result in a reduction of the productivity of North Sea plaice, a change in the distribution of the fisheries resource, and an aggravation of the current discarding problem within the fishery. Forecasting the impact of climate change on the productivity of North Sea plaice is critically dependent on our ability to forecast not only the food resources of plaice but also the spatial dynamics of the stock.

**26 April, 18:15 (A2-6345)**

### Linking climate, trophic interactions and fisheries: Threshold dynamics drive herring (*Clupea harengus*) growth in the central Baltic Sea

Michele Casini[1], Valerio **Bartolino**[1], Juan Carlos Molinero[2] and Georgs Kornilovs[3]

[1] Swedish Board of Fisheries, Institute of Marine Research, Box 4, Lysekil, 54321, Sweden. E-mail: michele.casini@fiskeriverket.se
[2] Leibniz Institute of Marine Sciences, (IFM-GEOMAR), Duesternbrooker Weg 20, Kiel, D-24105, Germany
[3] Latvian Fish Resources Agency, 8 Daugavgrivas Str., Riga, LV-1048, Latvia

How multiple stressors influence fish stock dynamics is a crucial question in ecology in general and fisheries science in particular. Using a time-series covering a 30-year period, we show that the body growth of the central Baltic Sea herring (both in terms of condition and weight-at-age) has shifted from being mainly driven by hydro-climatic forces to a density-dependent control. The shift in the mechanisms of regulation of herring growth has been triggered by the drastic increase in the abundance of sprat, the main food competitor for herring. Abundances of sprat above a threshold of ~$18*10^{10}$ individuals decouples herring growth from hydro-climatic factors (*i.e.* salinity), and becomes the main driver of growth variation. At high sprat densities, herring growth is considerably lower than at low sprat levels, independent of salinity conditions, indicative of hysteresis in the response of herring growth to changes in salinity. The threshold dynamic explains the changes in herring growth during the past three decades, and contributes to elucidating the parallel drastic drop in herring spawning stock biomass. The increase in sprat population has been caused by increased temperature and release from cod predation, confirming the importance of both climate and food-web structure in population dynamics. Studying the interplay between different stressors can provide fundamental information for the management of exploited resources. The management of the central Baltic herring stock should be adaptive and take into consideration the dual response of herring growth to hydro-climatic forces and food-web structure, providing a sound ecosystem approach to fisheries.

# A2 Oral Presentations: Day 2, April 27

**27 April, 9:00 (A2-6171)**

### A study on yellowfin tuna (*Thunnus albacares*) stocks and fishing conditions in relation to oceanic environmental variation in the Atlantic Ocean

Kuo-Wei **Lan**, Ming-An Lee and Hsueh-Jung Lu

Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, 2 Pei-Ning Rd., Keelung 20224, Taiwan, ROC
E-mail: aaman72422@msn.com

The yellowfin tuna is one of the major target species of the Taiwanese commercial tuna longline fishery in the Atlantic Ocean. In this study, we employed principle component analysis (PCA) to assess the strength of associations between Taiwanese LL fishery catch per unit effort (CPUE) in different subregions and various oceanic environmental factors from 1998 until 2007. Various environment variables were utilized including sea surface temperature (SST), sub-surface temperature, sea surface height (SSH), chlorophyll *a* concentration (Chl-*a*), net primary production (NPP) and the North Tropic Atlantic Index (NTA). The eight yellowfin tuna longline fishery sub-areas were delimited by ICCAT in the Atlantic Ocean. The distribution of yellowfin tuna was mostly concentrated in sub-area 3~4 and the catch percentage are more than 73.6%. In addition, he average CPUE of whole Atlantic Ocean was 0.77(inds/1000 hooks) but was 1.24(inds/1000 hooks) in sub-area 3 and 4. The GIS maps of SST, PP with CPUE showed the high CPUE areas have the east-west spatial variations and the high CPUE areas always focused on the high PP areas. The PCA indicated the highest relationship between CPUE, SST, sea temperature at 105~328m depth, SSH and NTA index factors (first component). The second component indicated that the catch of yellow-fin tuna was highly interrelated with the temperature subtraction of sub-area 3 and sub-area 4. Further, high CPUE of yellow-fin tuna are associated with increasing sub-surface temperature in 2003~2005, especially in 2005. It also reveals a yearly evolution of CPUE, catch and oceanic condition in the Atlantic Ocean.

**27 April, 9:15 (A2-6295)**

## Impacts of climate change on the distribution of blue marlin (*Makaira nigricans*) as inferred from data for longline fisheries in the Pacific Ocean

Nan-Jay **Su**[1], Chi-Lu Sun[1], André E. Punt[2] and Su-Zan Yeh[1]

[1] Institute of Oceanography, National Taiwan University, Taipei, 10617, Taiwan, ROC. E-mail: nanjay@ntu.edu.tw
[2] School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, 98195, USA

Blue marlin are distributed throughout tropical and temperate waters in the Pacific Ocean. However, the preference of this species for particular habitats may impact its distribution and vulnerability to being caught. Therefore, the relationship between spatio-temporal patterns of blue marlin abundance and environmental variables which may be impacted by climate change is examined using generalized additive models fitted to catch-effort data from longline fisheries and environmental data. The presence of blue marlin and the catch-rates given presence are modeled separately. Latitude, longitude, and sea-surface temperature explain the greatest proportion of the deviance. Spatial distributions of blue marlin abundance, based on combining the probability of presence and relative density given presence, indicate that there is annual variation in the distribution of blue marlin, and that the population apparently moved east during the 1997-1998 El Niño. Yearly patterns in the blue marlin distribution appear to be associated with El Niño through shifts in SST. This study shows that models of catch and effort which include environmental covariates could be used to explore future changes in spatial distribution given predictions from climate models.

**27 April, 9:30 (A2-6032)**

## Predicting the effects of climate change on bluefin tuna (*Thunnus thynnus*) spawning habitat in the Gulf of Mexico

Barbara **Muhling**[1], Sang-Ki Lee[2], Michael J. Schirripa[1], Walter Ingram[3] and John Lamkin[1]

[1] NOAA Southeast Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL, 33149, USA. E-mail: Barbara.Muhling@noaa.gov
[2] NOAA Atlantic Oceanographic and Meteorological Laboratories, 4301 Rickenbacker Causeway, Miami, FL, 33149, USA
[3] NOAA Southeast Fisheries Science Center, 151 Watts Ave., Pascagoula, MS, 39567, USA

Atlantic bluefin tuna is a wide-ranging species found throughout the Atlantic Ocean. However, within the western North Atlantic, significant spawning activity has not been recorded outside the Gulf of Mexico. While bluefin tuna can tolerate colder waters than other tunas, they are adversely affected by warm waters. Conditions within the Gulf of Mexico during the spring spawning season often approach the upper limits of tolerance for this species.

A predictive habitat model for bluefin tuna larvae in the Gulf of Mexico was produced using historical data. Larvae were unlikely to be collected within the Loop Current, warm eddies, or lower salinity continental shelf waters. Larvae were primarily collected between early-mid May, and mid June, suggesting a limited spawning window. Because of these preferences, and their reproductive biology, bluefin tuna populations show high vulnerability to the projected warming effects of climate change.

As a first step in determining climate change impacts on bluefin tuna spawning, we examined the ability of the 26 IPCC climate models to simulate 20$^{th}$ century Gulf of Mexico temperature distributions. Using the most suitable models, likely temperature scenarios for the next 100 years were projected under $CO_2$ emission scenario SRES A1B (720 ppm stabilization). Potential temporal and spatial changes in bluefin tuna spawning habitat in the Gulf of Mexico were then examined. This work forms the basis for future investigations into climate change effects on bluefin tuna spawning habitat, which will involve downscaling IPCC climate models to a regional scale using a high resolution ocean model.

**27 April, 9:45 (A2-6110)**

## Swordfish population dynamics in the Pacific Ocean

Melanie **Abecassis**[1], Patrick Lehodey[2], Inna Senina[2] and Jeffrey J. Polovina[3]

[1] Joint Institute for Marine and Atmospheric Research, University of Hawaii, 1000 Pope Rd., Honolulu, HI, 96822, USA
E-mail: melanie.abecassis@noaa.gov
[2] Collecte Localisation Satellites (CLS), Space Oceanography Division, 8-10 rue Hermès, 31520 Ramonville Saint-Agne, France
[3] Pacific Islands Fisheries Science Center, NOAA, 2570 Dole St., Honolulu, HI, 96822, USA

Swordfish (*Xiphias gladus*) is one of the most valuable pelagic resources for the Pacific Ocean longline fisheries. Yet, stock structure and spatial dynamics of this species are poorly known. For a proper sustainable management, we need to acquire a better knowledge of swordfish spawning and foraging grounds, and the mechanisms of migrations between them. Thus, we are adapting the SEAPODYM (Spatial Ecosystem And POpulation DYnamics Model) model, initially developed for tropical tuna species, to swordfish. SEAPODYM is a eulerian age-structured population dynamics model based on advection-diffusion-reaction equations. It uses oceanic environment simulated by ocean circulation and NPZD models to drive the spatial and temporal dynamics of both the biomass of prey functional groups and predator species (*i.e.*, here, swordfish). Estimation of parameters of the model can be optimized using assimilation of fishing data (catch and effort, and size frequencies). Once convergence is achieved, the model provides indices of spawning and foraging habitats, and the spatial distribution of different life stages (larvae, juveniles, and premature and mature adults) over time.

Once a satisfactory set of parameters has been obtained for a species, it is possible to use outputs of climate models (temperature, primary production, currents, oxygen concentration) as inputs in Seapodym to examine potential biomass trajectories or changes of habitat under different scenarios. This talk will present the model and current progress on adapting it to swordfish.

**27 April, 10:00 (A2-6227)**

## Climate change effect on the saffron cod *Eleginus gracilis* reproduction, stock, and fishery in the Japan Sea

Yury I. **Zuenko**, Lydmila A. Chernoivanova, Alexander N. Vdovin and Elena I. Ustinova

Japan Sea and North-West Pacific Oceanography, Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), 4 Shevchenko Alley, Vladivostok, 690950, Russia. E-mail: zuenko_yury@hotmail.com

Ice-fishing of saffron cod is developed in Peter the Great Bay where about 1000 tons of this species were caught annually until 1990. The catch decreased abruptly after the 1988/1989 climatic regime shift to warming and was only partially restored in 2000s, indicating a positive relationship between catch with winter severity. The relationship has one-year lag that allows one to discard the hypothesis that winter conditions directly influence ice-fishing and indicates that other factors, such as climate-driven changes in saffron cod reproduction may be responsible. Since this species spawns under the sea ice, we investigated whether spawning duration and year class strength were related to characteristics of winter severity including the sea ice conditions. We discuss the mechanisms by which global climate change appears to affect the local population of saffron cod and project future (21st century) changes in this population.

**27 April, 10:15 (A2-6239)**

## Incorporating climate variability into the assessment of Gulf of Alaska Pacific cod

Z. Teresa **A'mar**[1], André E. Punt[2] and Grant G. Thompson[1]

[1] NOAA Fisheries, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115, USA. E-mail: Teresa.Amar@noaa.gov
[2] School of Aquatic and Fishery Sciences, University of Washington, P.O. Box 355020, Seattle, WA, 98195-5020, USA

The exploration of the relationships between environmental forcing and recruitment and representing them within an operating model is a key component in the development of a management strategy evaluation framework which incorporates climate variability. The management strategy for the fishery for Pacific cod (*Gadus macrocephalus*) in the Gulf of Alaska (GOA) consists of an age-structured stock assessment model and a harvest control rule.

The relationships between age-0 abundance and climate indices, and the uncertainty associated with these relationships, were characterized within a statistical catch-at-age population dynamics operating model similar in structure to the stock assessment model for GOA Pacific cod. The operating model incorporated region-specific historical climate indices and was fitted to the data used for the stock assessment for GOA Pacific cod. The results from the operating model were compared with those from the 2009 stock assessment with respect to recruitment, stock status, and management measures. This comparison allowed for quantifying how the inclusion of climate data affected estimation precision, error, and bias.

**27 April, 10:30 (A2-6202)**

## Spatially resolved impact of temperature change on recruitment of sprat and cod in the Baltic Sea – From observation to bio-economic modeling

Rüdiger **Voss**[1], Hans-Harald Hinrichsen[2], Jörn O. Schmidt[1] and Martin F. Quaas[1]

1 Sustainable Fishery, Department of Economics, University of Kiel, Wilhelm-Seelig Platz 1, Kiel, 24118, Germany
E-mail: voss@economics.uni-kiel.de
2 Leibniz Institute of Marine Sciences, Düsternbrooker Weg 20, Kiel, 24105, Germany
3 Institute for Hydrobiology and Fisheries Science, Olbersweg 24, Hamburg, 22767, Germany

Assessment of climate change in the Baltic Sea revealed significant positive trends in the annual mean temperature. Especially during the last 10 to 15 years, extremely high NAO+ phases have been registered, being coupled to high sea surface temperatures. Studies of past and recent ecosystem changes have demonstrated the sensitivity of the Baltic Sea ecosystem to changing temperatures. For example, increased production of the sprat (*Sprattus sprattus*) population during the last decade has co-varied with high temperatures. In this study we investigate spatially-resolved temperature trends over a 25 year time period in the Baltic Sea obtained from hydrodynamic model simulations. We show that climate-driven changes in temperature affect the Baltic Sea area in a non-uniform way: Besides a general temperature increase, westerly winds have intensified, increasing the upwelling potential in some areas which is, in turn, coupled to lower than average temperatures. We calculate temperature trends in a spatial resolution of ¼ ICES rectangle (ca. 15x15nm) and a depth resolution of 10m intervals. We concentrate on months and depths strata which are most important for recruitment processes of the commercially important, as well as ecologically strongly interlinked species cod (*Gadus morhua*) and sprat. A spatially- and stage-resolved evaluation of temperature-dependant key processes for recruitment (*e.g.* egg mortality, egg phase duration, larval window of opportunity) is performed based on large-scale, collaborative European research programs such as CORE, STORE, and GLOBEC Germany. Finally, implications for future management are derived from an age-structured bio-economic model, using temperature-sensitive stock-recruitment relationships, including species interaction effects.

**27 April, 11:05 (A2-6191)**

## The rise and the fall of the northern blue whiting stock

Harald **Loeng**[1], Hjámar Hátún[2], Jens Christian Holst[1], Mark Payne[3] and Aril Slotte[1]

1 Institute of Marine Research, P.O. Box 1870 Nordnes, Bergen, 5817, Norway. E-mail: harald.loeng@imr.no
2 Faroe Marine Research Institute, Torshavn, Faroe Islands
3 Danish Institute of Aquatic Resources (DTU-AQUA) Charlottenlund Slot, 2920 Charlottenlund, Denmark

The northern blue whiting (*Micromesistius poutassou*) is a pelagic gadoid occupying mainly the waters between the spawning grounds west of the British Isles and the feeding areas in the Norwegian Sea and adjacent waters. The spawning stock of blue whiting increased dramatically in the late 1990s due to a succession of eight strong or extremely strong year classes. However, from 2005 the recruitment went back to the pre-1995 recruitment. Since 2005 the blue whiting stock has dropped quickly due to the collapse in recruitment and a large fishery. The sub-polar gyre may influence the spawning distribution and the current challenge is to explain how the changes in spawning distribution might influence the recruitment to the blue whiting stock. It is hypothesised that the mackerel feed on the eggs and larvae of blue whiting, thus affecting blue whiting recruitment negatively. The overlap in the spawning distribution of blue whiting with mackerel varies with the conditions in the sub-polar gyre. Larvae and young blue whiting feed on zooplankton in the Norwegian Sea. The biomass of zooplankton in the Norwegian Sea and adjacent areas has steadily decreased during the last fifteen years. In parallel the biomass

of pelagic fish (blue whiting, mackerel and Norwegian spring spawning herring) has increased. We hypothesize that variability in climate conditions explains changes in distribution while variability in predation by mackerel on eggs and larvae is the most likely direct causal mechanism affecting recruitment and variability in the feeding conditions in the nursery area likely having a secondary effect.

**27 April, 11:20 (A2-6028)**

## Effects of river temperature and climate warming on stock-specific survival of adult migrating Fraser River sockeye salmon (*Oncorhynchus nerka*)

Eduardo **Martins**[1], Scott Hinch[1,2], David Patterson[3], Merran Hague[3], Steven Cooke[4], Kristina Miller[5], Michael Lapointe[6], Karl English[7] and Anthony Farrell[8]

1 Centre for Applied Conservation Research, Department of Forest Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada. E-mail: egmartins@gmail.com
2 Institute for Resources, Environment and Sustainability, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada
3 Fisheries and Oceans Canada, Cooperative Resource Management Institute, School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC, V5A 1S6, Canada
4 Institute of Environmental Science and Department of Biology, Carleton University, Ottawa, ON, K1S 5B6, Canada
5 Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
6 Pacific Salmon Commission, Vancouver, BC, V6E 1B5, Canada
7 LGL Limited, 9768 Second St., Sidney, BC, V8L 3Y8, Canada
8 Department of Zoology and Faculty of Land and Food Systems, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada

Mean summer water temperatures in the Fraser River (British Columbia, Canada) have increased by ~1.5°C since the 1950's. In recent years, record high river temperatures during spawning migrations of Fraser River sockeye salmon (*Oncorhynchus nerka*) have been associated with high mortality events, raising concerns about long-term viability of the numerous natal stocks faced with climate warming. In this study, the effect of freshwater thermal experience on spawning migration survival was estimated by fitting capture-recapture models to five years of telemetry data collected for ~1,500 adults from four Fraser River sockeye salmon stock-aggregates (Chilko, Quesnel, Stellako-Late Stuart, and Adams). Survival of Adams sockeye salmon was the most impacted by warm temperatures encountered in the lower river, followed by that of Stellako-Late Stuart and Quesnel. In contrast, survival of Chilko fish was insensitive to temperature. The survival-temperature relationships were used to predict historic (1961-1990) and future (2010-2099) survival under simulated lower river thermal experiences for the Quesnel, Stellako-Late Stuart, and Adams stocks. A decrease of ~15% in survival of all these stocks was predicted by the end of the century if the Fraser River warms as expected. However, the decrease in future survival of Adams sockeye salmon would occur only if fish continue to enter the river abnormally early, towards warmer periods of the summer, as they have done since 1995. The survival estimates and predictions presented here are likely optimistic and emphasize the need to consider stock-specific responses to temperature and climate warming into fisheries management and conservation strategies.

**27 April, 11:35 (A2-6179)**

## Long-term fluctuations in somatic growth, survival, and population dynamics of Hokkaido chum salmon, *Oncorhynchus keta,* linking to climate changes

Hyunju **Seo**[1], Masa-aki Fukuwaka[2] and Masahide Kaeriyama[3]

1 Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido, 041-8611, Japan
E-mail: uagiri@hanmail.net
2 Subarctic Fisheries Resources Division, Hokkaido National Fisheries Research Institute, 116 Katusurakoi, Kushiro, 085-0802, Japan
3 Faculty of Fisheries Sciences, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido, 041-8611, Japan

We revealed the effects of regional and larger spatial scales of climatic/oceanic condition on growth, survival, and population dynamics of Hokkaido chum salmon (*Oncorhynchus keta*) using path analysis. Variability in growth of chum salmon at age-1 to -4 in the North Pacific including Okhotsk Sea and Bering Sea was estimated based on the back-calculation method using scales of 4-year-old adults returning to the Ishikari River of Hokkaido Island in Japan during 1945-2005. Hokkaido chum salmon had higher growth rates at age-1 but lower growth rate sat age-2, -3, and -4 since the 1980s. Path analysis indicated that the growth at age-1 in the Okhotsk Sea was directly impacted by warmer sea surface temperature (SST) associated with global warming. The increased growth at

age-1 resulted in higher rates of survival and larger age-1 population sizes. In the Bering Sea, subsequently, large age-1 population sizes led to decreased growth at age-3 and indirectly smaller fork length of adults, despite no relation between SST, zooplankton biomass, and the growth at age-2 to -4. Therefore, faster growth at age-1 relating to global warming is expected to increase the survival of age-1 chum salmonand, by doing so, will lead to density-dependent reductions in the growth at age-2 to -4 individuals and maturation impacts on this population due to limits in the carry capacity of the Bering Sea.

**27 April, 11:50 (A2-6173)**

## Investigating the roles of climate, density-dependence and fishing on long-term and large-scale changes in recruitment, growth, maturity and distribution of Pacific halibut

Juan L. **Valero**, Steven R. Hare and Bruce M. Leaman

International Pacific Halibut Commission, P.O. Box 95009, Seattle, WA, 98145-2009, USA. E-mail: juan@iphc.washington.edu

Pacific halibut in Canada and USA have been commercially exploited since 1888 and have been managed by the International Pacific Halibut Commission (IPHC) since 1923. During that time the understanding and modeling of population processes, as well as the processes themselves, have changed significantly. Recruitment shows the effects of alternating productivity regimes correlated to the Pacific Decadal Oscillation. Long-term and large-magnitude changes in growth are potentially linked to abundance or competition. Current declines in size at age affects the maturity schedule, the proportion of females caught, and decreases exploitable biomass. Analyses of historical distributions of abundance indicate large temporal changes and spatial shifts between northwest and southeast regions. The IPHC harvest policy was developed to be robust to variability and uncertainty in the aforementioned processes. However, a major assumption regarding the understanding and modeling of halibut dynamics (that ontogenetic migration ended when halibut recruit to the commercial fishery) has been refuted. A recent stock-wide tagging study shows that halibut continue migrating at rates high enough to impact halibut dynamics under exploitation. Migration has considerable effects on the spatial scope of the assessment, spatial apportionment of catches and spatial distribution of bycatch impacts. The above effects and the potential effects of migration on processes not yet evaluated, led to an ongoing re-evaluation of the IPHC harvest policy. Furthermore, the harvest policy re-evaluation includes revisiting the roles of climate, density-dependence, and historical fishing patterns on halibut dynamics under exploitation.

**27 April, 12:05 (A2-6156)**

## Past, present and future of Japanese common squid, *Todarodes pacificus* (Cephalopoda: Ommastrephidae)

Yasunori **Sakurai**[1], A.L. Rosa[1] and J. Yamamoto[2]

[1] Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido, 041-8611, Japan
E-mail: sakurai@fish.hokudai.ac.jp
[2] Field Science Center for Northern Biosphere, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido, 041-8611, Japan

The Japanese common squid, which has a 1-year life cycle, is one of the most important commercially exploited squid species in the world. It is distributed in the Sea of Japan, the East China Sea, and the Oyashio and Kuroshio current systems. It consists of three subpopulations with different peak spawning seasons; summer, autumn and winter, with the later two being the largest and most important. Autumn spawning occurs mainly in the southern Sea of Japan and the Tsushima Strait, while winter spawning occurs in the East China Sea. *T. pacificus* produce gelatinous egg mass containing many small eggs. These egg masses are thought to occur within or above the pycnocline at temperatures suitable for egg development. We estimated from laboratory studies that hatchlings (<1mm ML) will survive in the surface water at temperatures between 18-24°C, with highest survival between 19.5-23°C. After hatching, the paralarvae presumably ascend from the mid layer near the pycnocline to the surface layer above the continental shelf and slope and are transported into convergent frontal zones. We analyzed long-term changes of environmental variables, such as SST and wind, on the distribution of spawning areas of *T. pacificus* (1978 to 2010) in the Sea of Japan and East China Sea, Furthermore, we attempted to predict the distribution of spawning areas and life cycle characteristics of *T. pacificus* during the 21st Century based on the Global Warning Scenario (IPCC, International Panel of Climate Change) using the Earth Simulation System (FRCGC, Frontier Research Center of Global change, Japan).

**27 April, 12:20 (A2-6250)**

## Differing response of herring stocks to ecosystem forcing in the California and Gulf of Alaska Current systems

Jacob F. **Schweigert**[1], Jennifer Boldt[1], Linnea Flostrand[1], Peter Olesiuk[1], Sherri Dressel[2] and Ryan Watanabe[3]

1 Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
E-mail: Jake.Schweigert@dfo-mpo.gc.ca
2 Alaska Department of Fish and Game, P.O. Box 240020, Douglas, AK, 99824, USA
3 California Department of Fish and Game, P.O. Box 1650, Bodega Bay, CA, 94923, USA

Pacific herring populations at four locations within the California Current and Gulf of Alaska were examined and compared for response to environmental influences on marine productivity or bottom-up forcing and top-down effects due to changing marine mammal predation as these populations have recovered or collapsed in the two oceanographic systems. Herring populations in San Francisco Bay and on the west coast of Vancouver Island within the California Current have experienced a long term decline as ocean conditions have warmed and marine mammal populations have recovered from historic commercial harvest. In contrast, populations in Sitka and Prince Rupert have remained stable or increased within the Gulf of Alaska as mammal predators have declined and ocean conditions warmed. We compared the average recruitment rates, growth rates, and mortality rates in the four herring populations in relation to changes in average predator population abundance levels and food availability. It appears that reduced plankton availability in combination with increased predation has impacted the recruitment and productivity of herring in the California Current system to a greater degree than in the Gulf of Alaska. Implications of these results are discussed with respect to effects of climate change on the long term sustainability of these populations throughout the North Pacific.

**27 April, 12:35 (A2-6338)**

## Responses of anchovy and sardine spawning to physical and biological factors in the Kuroshio and California Current systems: Interspecific and intersystem comparison

Akinori **Takasuka**[1], Sam McClatchie[2], Ed Weber[2], Yoshioki Oozeki[1], Takahiko Kameda[1], Yuichi Hirota[3] and Hiroshi Okamura[4]

1 National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa, 236-8648, Japan. E-mail: takasuka@affrc.go.jp
2 Southwest Fisheries Science Center, NOAA, 8604 La Jolla Shores Dr., La Jolla, CA, 92037-1508, USA
3 National Research Institute of Fisheries Science, Fisheries Research Agency, 6-1-21 Sanbashidori, Kochi, Kochi, 780-8010, Japan
4 National Research Institute of Far Seas Fisheries, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa, 236-8648, Japan

Spawning responses to physical and biological factors were examined for Japanese anchovy (*Engraulis japonicus*) and Japanese sardine (*Sardinops melanostictus*) in the Kuroshio Current system, and northern anchovy (*E. mordax*) and California sardine (*S. sagax*) in the California Current system. Species-specific patterns were extracted from long-term data sets of the egg surveys off the Pacific coast of Japan, from 1978 to 2007, and the CalCOFI surveys off California and Baja California from 1951 to 2008. Generalized additive models were used to relate egg presence/absence to sea surface temperature, sea surface salinity, zooplankton volume, and chlorophyll *a* concentration. Spawning anchovy and sardine showed species-specific responses to temperature and salinity that differed between species within each current system and between the two current systems. Although the responses to zooplankton and chlorophyll were fairly consistent between the two systems, there were species-specific patterns, which could be interpreted in the context of differential energy allocation strategies for reproduction. On a continuum between reliance on income and capital for fueling reproduction, Japanese anchovy was clearly an income species whereas Japanese sardine and California species showed more reliance on capital. Differences between anchovy and sardine were greater in the Kuroshio than in the California Current system. The anchovy–sardine relationships between the two systems appeared reversed when considering the responses to physical factors (temperature and salinity) and not reversed, but quite different, in the responses to biological factors (zooplankton and chlorophyll). These different biological responses constitute a key factor in understanding climate effects on congeneric species.

**27 April, 12:50 (A2-6196)**

## Climate-induced changes in distribution of Northwest Atlantic fish and invertebrates: Implications for management

Janet A. **Nye**[1], Jason S. Link[1] and Jonathan A. Hare[2]

[1] National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA, 02543, USA
E-mail: janet.nye@noaa.gov
[2] National Marine Fisheries Service, Northeast Fisheries Science Center, 28 Tarzwell Dr., Narragansett, RI, 02882, USA

The hypothesized first response of organisms to warming temperatures associated with climate change is a shift in spatial distribution and several recent studies have detected such responses in many ecosystems. Similarly, in a meta-analysis of 36 fish stocks and 6 invertebrates on the Northeast US coast, we found that over half of these fish and invertebrates exhibited distributional responses consistent with warming, including a poleward shift in mean center of biomass, an increase in mean depth, and an expansion or contraction of their range. Distributional changes were highly correlated with the Atlantic Multidecadal Oscillation, but the magnitude of change was dependent on the biogeography of each species. Stocks at the southern extent of their range exhibited dramatic poleward shifts, while minimal changes in center of biomass were observed in stocks with distributions limited to the Gulf of Maine. Such shifts in distribution have important implications for the rebuilding plans for some stocks and suggest that we continually re-evaluate the unit stock definition of species as climate change continues to affect species spatial distribution and population dynamics. We discuss spatial shifts and recruitment variability of selected species to highlight how changes in these responses to climate change may affect stock assessments and management advice.

**27 April, 13:05 (A2-6019)**

## Now you see me, now you don't: Uncertainties in projecting future spatial distribution of marine populations

Benjamin **Planque**[1], Edwige Bellier[2], Frida Ben Rais Lasram[3] and Christophe Loots[4]

[1] Institute of Marine Research, Postboks 6404, 9294 Tromsø, Norway. E-mail: Benjamin.planque@imr.no
[2] Norwegian Institute for Nature Research (NINA), 7485 Trondheim, Norway
[3] Laboratoire Ecosystèmes et Ressources Aquatiques, Institut National Agronomique de Tunisie, 43 Ave. Charles Nicolle, 1082 Tunis, Tunisia
[4] Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Laboratoire Ressources Halieutiques, 150 quai Gambetta, BP699, F-62321 Boulogne sur mer, France

Climate change, by altering the physical environment of marine species, is expected to result in alteration of the distribution of marine populations. Predicting the nature and magnitude of these changes relies mostly on observations of populations' response to past climate variability. As future climate variations are expected to depart from past ones, such projections remain highly uncertain. In this contribution, we review the fundamental assumptions behind the most common species and population distribution models. We argue that most of the uncertainties in future projections result from model uncertainties engendered by gaps in knowledge on the processes controlling spatial distribution and on how these may evolve in the future. Most available methodologies present very high levels of uncertainty and may not be suitable to provide reliable guidance on what future spatial distributions of marine populations may look like. On the other hand, they constitute valuable tools for understanding underlying processes and exploring the consequences of possible future management strategies.

# A2 Posters

### A2-6022

## Possible inner causes for correcting "climatic" trends in pink salmon

Alexander M. **Kaev** (presented by A. Velikanov)

Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO), 196 Komsomolskaya St., Yuzhno-Sakhalinsk, 693016, Russia
E-mail: kaev@sakhniro.ru

Pink salmon is thought to be a possible indicator species, sensitive to climate-driven environmental change. However, pink salmon abundance, biological indices and migration timing may all be influenced via changes in the relative composition of different sub-components of this stock (*e.g.*, early versus late sub-components identified within Aniva Bay (southern Sakhalin Island) and Iturup Island (Kuril Islands) stocks. Despite biological differences, both sub-components display trends towards increasing male size of males and decreasing relative fecundity of females. Higher size-specific egg production by early versus late females reflects higher mortality (mean abundance of the early component is lower and more temporally variable). Freshwater spawning conditions influence the ratio of abundance of early versus late pink salmon. Opposite long-term trends in abundance of late and early salmon have been observed for Aniva Bay and Iturup Island that weakly track changes in the Pacific Decadal Oscillation (PDO) climate index and may be related to cycles of solar activity. Changes in pink salmon length are not correlated to the PDO. A ratio change was noted for male and female body lengths: females became relatively larger when growth slowed. Since female length is positively correlated to fecundity, the increased female length may a population response that increases the probability of successful reproduction when feeding conditions change for the worse.

### A2-6030

## Inter-cohort growth rate changes of common sardine (*Strangomera bentincki*) and their relationship with environmental conditions off central southern Chile

Claudio **Castillo-Jordán**[1,3], Luis A. Cubillos[2,3] and Eduardo Navarro[4]

1 Programa de Magíster en Ciencias con mención en Pesquerías
2 Programa de Doctorado en Oceanografía
3 Laboratorio de Evaluación de Poblaciones Marinas (EPOMAR), Departamento de Oceanografía, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, Casilla 160-C, Concepción, Chile. E-mail: clacastillo@udec.cl
4 Centro Regional de Estudios Ambientales (CREA), Universidad Católica de la Santísima Concepción, Caupolicán 491, Concepción, Chile

The inter-cohort variability in the von Bertalanffy (VB) growth parameters of common sardine (*Strangomera bentincki*) was analyzed between 1990 and 2007. Time series of monthly length-frequency data were used to calculate somatic growth rate (*G*) of cohorts throughout the study period. The VB growth parameters were estimated using a nonlinear mixed-effects model by considering that population growth parameters have a common distribution and that cohort-specific parameters can be treated as random effects. The best model explaining inter-cohort changes in growth included $L_{\infty}$ (asymptotic length) and *K* (growth coefficient) as random effects. Sardine cohort growth (during the initial, fast-growth phase) was significantly different after 1998. Values of *G* were higher for cohorts recruited between 1990 and 1997 compared to cohorts between 1999 and 2006. This significant change in G coincided with a colder period established in the area after 1998 and changes in Ekman transport dynamics. A significant and inverse relationship was found between *G* of cohorts and Ekman transport during the first fast-growth period (October to March) that explained 36 to 39% of the observed growth variability. Except for the anomalously high growth rate of the 1998 cohort, sea surface temperature anomalies significantly explained 47 to 57% of the observed variability in *G* of the cohorts. Although changes in environmental conditions can explain a small but significant fraction of the observed variability, it is likely that intrinsic factors also play important roles in determine the growth dynamics of common sardine in southern Chile and elsewhere.

**A2-6033**

## Patterns and processes underlying Pacific hake (*Merluccius productus*) migrations: Progress on developing forecast tools to predict distribution and density

Melissa A. **Haltuch**[1], Carrie Holt[2], André E. Punt[3] and M. Elizabeth Clarke[1]

[1] Northwest Fisheries Science Center, NOAA Fisheries, NOAA, 2725 Montlake Blvd. East, Seattle, WA, 98112, USA
E-mail: Melissa.haltuch@noaa.gov
[2] Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
[3] School of Aquatic and Fishery Sciences, Box 355020, University of Washington, Seattle, WA, 98195-5020, USA

The spatial distribution of Pacific hake (*Merluccius productus*) exhibits strong environmentally-driven inter-annual variation during the stock's annual northerly migration, impacting monitoring, assessment, and management of this species. Spawning and rearing habitat temperatures and strength of alongshore currents are hypothesized drivers of that variation, both of which may be impacted by global climate change. Prediction of hake distribution is important for long-term planning under future climate scenarios, and short-term decisions. Specifically, hake management would be enhanced via optimized survey design and planning from improved estimates of hake distribution and abundance. Given the ability to predict the distribution and abundance of hake prior to a survey, survey effort could be distributed to minimize (expected) variance. Substantial benefits, in terms of more precise estimates of abundance, could be possible for the hake survey off the west coast of North America which forms the basis for stock assessment and management advice. This presentation discusses the development of a forecast tool for predicting hake distribution and abundance based on fitting spatial time-series models with environmental covariates. Previous studies have modeled hake distribution and density. However the covariates for this project are derived from real-time satellite data and short-term ocean model forecasts, and hence have the potential for a more spatially explicit and extensive predictive tool than previous efforts. While these forecasts focus on time scales from weeks to seasons, developing the ability to produce reliable short-term forecasts for hake is a precursor to forecasting the longer-term impacts of global climate change on the hake stock.

**A2-6041**

## Classifying the spatial structure of different spawning populations of commercially important Atlantic and Mediterranean Sea by otolith elemental composition

Mei-Yu **Chang** and Audrey J. Geffen

Department of Biology, University of Bergen, Post Box 7800, Bergen, N-5020, Norway. E-mail: Audrey.Geffen@bio.uib.no

One of the most likely scenarios of the impact of climate change on marine fish populations is the change in geographic ranges and altered distributions of locally adapted populations within species. Methods of monitoring such changes must combine immediate observations of population structure with methods that can reveal both past and present spatial patterns. Otoliths are the first calcified tissues to be formed in fish. The core of the otolith is formed during the pelagic larval stage, and contains a record of growth and the environmental cues that reflect spawning and larval drift. Within species there are often striking regional differences in otolith structure and elemental composition that are characteristic of different populations. Combining the information from otoliths, which represent the environment signals, and genetic techniques, which focus on the evolutionary scale, might give us more insight regarding the structure of stocks. Atlantic Cod (*Gadus morhua* L.), herring (*Clupea harengus*), European hake (*Merluccius merluccius*) and common sole (*Solea solea*) are four commercially-important and widely-distributed species in the Atlantic Ocean and Mediterranean Sea. The objectives of this study were to examine the regional differences in the chemical signal in otolith cores and classify the different spawning groups within each of the species. The impact of climate change, including temperature and acidification, can be evaluated by comparing present and past population structure. The methodology includes both laboratory and field experiments to produce otolith material reflecting different regional environments.

### A2-6058

## Herring recruitment in the Baltic Sea: From observations to projections

Valerio **Bartolino**[1], Piotr Margonski[2], Massimiliano Cardinale[1], Martin Lindegren[3], Hans Linderholm[4], Hakan Wennhage[1] and Michele Casini[1]

[1] Institute of Marine Research, Swedish Board of Fisheries, Lysekil, 45321, Sweden. E-mail: valerio.bartolino@fiskeriverket.se
[2] Sea Fisheries Institute, Gdynia, 81332, Poland
[3] National Institute of Aquatic Resources, Technical University of Denmark, Charlottenlund, 2920, Denmark
[4] Regional Climate Group, University of Gothenburg, Gothenburg, 40530, Sweden

Environmental variability and parental effects are two of the main forces driving temporal dynamics of recruitment in herring stocks in the Baltic Sea. Applying recruitment models recently developed for the herring stocks in the Central Baltic Sea and Gulf of Riga, we tested the effects of changes in water temperature predicted by different climatic scenarios for the next three decades, on herring recruitment trajectories under different fishing mortality levels. Our recruitment projections integrated estimates made by regional climate models and from a linear state-space food web model. Sea surface temperatures (SST) predictions represented the primary biologically-independent source of variability and uncertainty in our system. Both direct and indirect processes that link herring recruitment to SST variations were taken into account. The main indirect effects of temperature were transferred to the herring parental stock and finally to recruitment through the food web and the tight trophic relationships between zooplankton, sprat, herring and cod. Our projections suggested that recruitment will fluctuate at previously observed levels or will increase according to the severity of the warming scenario. The parental stock will have minor variations from the current levels and mostly temperature will drive the recruitment process. Uncertainties associated to the climate predictions were propagated across the food web and recruitment models to assess their effects on recruitment projections for the next decades. Our study showed how coupling climatic and biological models is possible and in our opinion should be promoted to understand the consequences of exploitation on natural resources in a fast changing environment.

### A2-6059 (***Cancelled***)

## Modelling the demography of *Calanus sinicus* in the Yellow Sea Cold Water Mass

Guimei **Liu**[1], Song Sun[2] and Hui Wang[1]

[1] National Marine Environmental Forecasting Center, Beijing, 100081, PR China. Email: liugm@nmefc.gov.cn
[2] Institute of Oceanology, Chinese Academy of Sciences, Qingdao, 266071, PR China

*Calanus sinicus (C. sinicus),* which is the main food for the anchovy and sardines, is a dominant copepod in the Yellow Sea and has been specified as the key target species in the China-GLOBEC program. All stages of *C. sinicus* can be found throughout the year in the Yellow Sea with a primary peak in abundance occurring in the spring (from May to July) driven by seasonal changes in water temperature and food supply and a second, smaller peak observed in the autumn. Abundance and egg production rates are both very lower in winter due to sub-optimal (low) temperatures and prey levels. The species is also not frequently encountered in shallow, coastal waters during the summer. This copepod mainly resides in the Yellow Sea Cold Water Mass (YCWM), where temperatures above and below the strong thermocline are >25ºC and ~8ºC, respectively. In this paper, a three-dimension coupled physical and biological model is described for *C. sinicus* in the Yellow Sea. The physical model used is the Princeton Ocean Model (POM) while the biological model is a simple temperature-dependent stage based model including eggs, N1 to CI, CII to CVI. The model was capable of reproducing observed phenomenon including that high abundance of copepodites that typically occurs in YSCWM in August. Passive tracer simulations illustrated that the weak residual flow at the bottom layer constrained the copepodites of *C. sinicus* away from the YSCWM.

## A2-6060

## Association of larval fish abundance with mesoscale eddies in the Gulf of Alaska

Elizabeth **Atwood**[1], John K. Horne[2], Janet T. Duffy-Anderson[3] and Carol Ladd[4]

[1] Quantitative Ecology and Resource Management, University of Washington, P.O. Box 355020, Seattle, WA, 98185-5020, USA
E-mail: eatwood@u.washington.edu
[2] School of Aquatic and Fisheries Sciences, University of Washington, P.O. Box 355020, Seattle, WA, 98185-5020, USA
[3] NOAA Fisheries, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115-0070, USA
[4] NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA, 98115-0070, USA

Larval fish dispersal trajectories from spawning grounds to juvenile nursery habitats influence growth and survival. Trajectories are affected by environmental factors such as currents, winds, and basin-wide atmosphere-ocean coupling. Mesoscale eddies propagating along the Gulf of Alaska shelf-break can increase cross-shelf flow and affect nutrient, chlorophyll, and zooplankton communities in the basin. Yet association between eddy activity and shelf ichthyoplankton community composition has received little attention. Our objectives were to investigate association between eddy activity and annual shelf larval fish abundances, and to compare effects of eddies and other environmental processes on larval fish abundances at local and basin scales. Monthly eddy kinetic energy (EKE) was used to measure eddy activity and was compared to springtime larval fish abundance estimates for eleven common fish species in Shelikof Strait, Alaska. We used multivariate and regression techniques to evaluate associations between larval fish abundances and EKE. Annual relative abundances of larval fish during high EKE years were unequal to years with low EKE ($p < 0.001$). Some species were more abundant in high EKE years, while other species were less abundant. We grouped species by life history characteristics for regression analyses, and groups were supported by larval abundance cluster analysis (Non-metric Multidimensional Scaling, stress = 8.17). Importance of EKE in predicting larval fish abundance was comparable to other atmospheric-oceanographic variables ($p < 0.05$). We propose mesoscale eddies should be included in future studies of physical factors influencing ichthyoplankton dispersal, an essential component in determining how climate change may impact future fish populations.

## A2-6070

## Pattern of habitat preference by three small pelagic species in the southern Benguela during high and low biomass periods

Nandipha M. **Twatwa**, Dawit Yemane and Janet C. Coetzee

Marine and Coastal Management, Department of Environmental Affairs, Private Bag X2, Rogge Bay, 8012, South Africa
E-mail: Natwatwa@deat.gov.za

Environmental factors that govern habitat preference and impact on fisheries resources can be assessed by linking prevailing environmental conditions to the abundance and distribution of individual species. Spatially-explicit estimates of the abundance of anchovy (*Engraulis capensis*), sardine (*Sardinops sagax*) and round herring (*Etrumeus whiteheadi*) were combined with oceanographic data bases to reveal the habitats utilized by these three species at different biomass levels in the southern Benguela upwelling ecosystem. Populations of these species are of great socio-economic and ecological importance to the region and are vulnerable to change in response to environmental fluctuations. To understand the preferred environmental envelop, a single parameter quotient (SPQ) method with randomization and non-linear model was used. Results indicated uneven distributions of abundance of these small pelagic species across gradients of environmental variables. During high and low biomass levels, anchovy preferred sea surface temperatures between 18.5 to 19.5°C, and 17.5 to 18.5°C, respectively, which were cooler than those preferred by sardine (19.5°C and 20.5-21.5°C, respectively). During low biomass periods, anchovy's preferred depths of 15 to 35 m; whereas this species was found at greater depths (25 to 35 m) when populations were at low levels. Compared to anchovy, sardine was captured in a broader range of depths (15 to 35 m) at high biomass levels. Round herring (redeye) had a wider depth preference (75 to 125 m and 155 to 165 m) during high biomass but utilized a restricted range of depths (85 to 135 m) during period of low abundance. This species was found in the coolest waters (between 9.5 and 11.5°C) and occurred at greater depths and at lower levels of dissolved oxygen ($<4.5 ml.l^{-1}$) than the other two species. This basic biological information is an essential step towards understanding habitat partitioning and the population dynamics, and improving the management of these species.

**A2-6077**

## Environmental changes caused recent increase in abundance of rock cod, *Patagonotothen ramsayi* in the Southwest Atlantic

Alexander **Arkhipkin** and Vladimir Laptikhovsky

Falkland Islands Government Fisheries Department, P.O. Box 598, Stanley, FIQQ 1 ZZ, Falkland Islands
E-mail: aarkhipkin@fisheries.gov.fk

The rock cod, *Patagonothen ramsayi* (Nototheniidae) is an abundant demersal small-bodied fish (adult size 30-35 cm) that is widely distributed along the Patagonian Shelf in the Southwest Atlantic. This species was a common bycatch in bottom trawl fisheries around the Falkland Islands with the total annual catch of 400-4,000 t in 1990-2004. Since 2005, rock cod abundance started to increase with total annual catches attaining 30,157 t in 2007 and 60,209 t in 2008. This explosion in abundance was initiated after the yearclass associated an unusually cold year (2002) that was followed by a chain of warm years (2003-2007) that had relatively high water temperatures on the shelf. It probable that increased rates of growth and survival led to the marked increase in population biomass of this species in this area. More rapid growth is supported by observed increases in the length of juveniles captured from 2003 (15-21 cm) to 2008 (22-26 cm) along the southern shelf. Possible effects of the recent environmental changes to the fishery management in the Falkland Islands are discussed.

**A2-6082**

## The first annulus of otoliths: A tool for studying intra-annual growth among walleye pollock (*Theragra chalcogramma*)

Matthew T. **Wilson**, Kathy Mier and Annette Dougherty

Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA, 98115, USA. E-mail: matt.wilson@noaa.gov

In temperate and sub-polar oceans, coastal populations of adult fishes are sustained by influxes of juveniles from disparate geographic locations. Individual growth occurs mostly during summer. Growing season characteristics (*e.g.* timing, duration, maximum growth rate) relate to life history strategy and are subject to climate-mediated changes in bottom-up forcing. Seasonal fluctuation in growth is reflected in otoliths by translucent (annuli) and opaque growth zones. Walleye pollock from the 2000 year class were available for this study from 14 research cruises conducted in the western Gulf of Alaska (GOA) and eastern Bering Sea (EBS). Study objectives were to: 1) use juveniles to determine the timing of first annulus formation, and 2) define the season of yearling growth. Fifty percent of juveniles exhibited an annulus on 16 March 2001 (± 11 d 95% CI). The growing season for yearlings lasted 205 d (20 March to 12 October 2001); growth rate peaked on 2 July (0.58 mm $d^{-1}$) and declined thereafter into autumn. Growing season initiation coincided with springtime warming and concluded in late summer as water temperatures exceeded the juvenile physiological optimum. If the climate continues to warm, as predicted by the IPCC, we hypothesize that the GOA pollock growing season will first advance (start earlier) and then shorten as temperatures exceed the physiological maximum for a longer fraction of the summer.

**A2-6083**

## Warming seas and the migration of Atlantic mackerel

Kathryn **Hughes**[1], Mark P. Johnson[1] and Leonie Dransfeld[2]

[1] Lab 203 MRI Annexe, Martin Ryan Institute, National University of Ireland, University Rd., Galway, County Galway, Ireland
E-mail: K.Hughes4@nuigalway.ie
[2] Marine Institute of Ireland, Rinville, Oranmore, Galway, County Galway, Ireland

Atlantic mackerel (*Scomber scombrus*) is a highly migratory species that is of high commercial value, having total fishery catch worth €600 million, representing a value of almost €5 million to Ireland. The consensus migration pattern is for feeding during winter months in the North Sea and the south of the Norwegian Sea, followed by movement of the species to the Western European continental shelf edge during the spring and summer months where spawning occurs. Long-term mackerel egg data from the ICES triennial survey (11 sample years from

1977 – 2007) were examined to investigate distribution and abundances of *S. Scombrus* spawning events. The centres of gravity, inertia and anisotropy were calculated for egg density (all stages) and sea surface temperature. The analyses supported previous studies; concluding that spawning events occur along the 200m isobath, with spawning commencing around the Bay of Biscay in March/April and ending further North in Irish waters. The centre of gravity of stage 1 eggs has shifted north during the ICES surveys, independent of effort, with an increase in the inertia or spread, of egg density. The centre of gravity of sea surface temperature (SST) remained within a small window between 12 to 14°C, suggesting that *S. scombrus* tracks those temperatures and that SST plays an important role in spawning events. Spatial and temporal gradients in temperature are being tested for evidence of migration cues and associations with the spread of spawning aggregations.

**A2-6092**

## Thermal acclimation by a coral reef fish

Jennifer M. **Donelson**, Philip L. Munday and Mark I. McCormick

ARC Centre of Excellence for Coral Reef Studies and School of Marine and Tropical Biology, James Cook University, Townsville, Queensland, 4811, Australia. E-mail: Jennifer.Donelson@jcu.edu.au

The capacity for organisms to acclimate and adapt to global warming is of vast importance for establishing the likelihood of persistence of current populations. Climate change is predicted to increase sea temperature in the tropics by up to 3.0°C over the next decade. While there is evidence that water temperature affects metabolism, growth and condition of coral reef fish, it is unknown if juveniles have the potential to acclimate when given adequate time. Offspring were produced by breeding pairs under current-day temperature conditions and split into three treatments. Temperature treatments were the current-day average and temperatures that could become close to the average for this region over the next 50-100 years (+1.5°C and +3.0°C than current-day). After one year, testing of resting metabolic rates was completed at the mean summer temperature for the three treatments. Fish which developed at the highest treatment temperature of +3.0°C than the current-day average had significantly lower $MO_{2Rest}$ than fish kept at the other lower treatment temperatures (current day and +1.5°C) and tested at the summer average of the +3.0°C treatment. The reduction in $MO_{2Rest}$ of up to 69 mg $O_2$ $kg^{-1}$ $h^{-1}$ is likely to represent benefits to daily energy expenditure during the summer. However, these fish were found to have reduced growth and were in poorer condition suggesting that production of acclimation to elevated temperature potentially also represented an energetic cost.

**A2-6094**

## Comparison of swimming performance at various acclimation temperatures for teleosts inhabiting Japanese coastal waters

Yasuo **Itoh**[1], Yukihiko Watanabe[1], Yukio Nakamura[2], Shuji Tsuchida[1], Hideaki Kinoshita[1], Takumi Setoguma[1] and Yasushi Minowa[3]

[1] Central Laboratory, Marine Ecology Research Institute, 300 Iwawada, Onjukumachi, Isumigun, Chiba, 299-5105, Japan
E-mail: itoh@kaiseiken.or.jp
[2] Marine Ecology Research Institute, Touwa-Edogawabashi Bldg. 7F, 347 Yamabukicho, Shinjuku-ku, Tokyo, 162-0801, Japan
[3] Demonstration Laboratory, Marine Ecology Research Institute, 4-7-17 Arahama, Kashiwazaki, Niigata, 945-0322, Japan

The swimming performance of 24 species of Japanese coastal marine teleosts was measured using a circulating water treadmill at various acclimation temperatures. Trial fishes were acclimated at the three to five different fixed temperatures for two or more weeks. The swimming curve formula, $(V/L) \cdot T^{\alpha} = K$ (V: flow velocity, L: body length, T: swimming duration, α&K: constants), was used for calculating three swimming performance parameters, the maximum swimming speed, maximum sustained speed and swimming ability index $\left(\text{s.a.i.} = \int_0^{3600} V\,dt/10^4\right)$. The maximum swimming speeds were 6.7-25.1 body length (BL)/second at 10-32°C whereas the maximum sustained speeds, 2.9-12.9 BL/s at 10-32°C. The ratio of the maximum sustained speed to the maximum swimming one was 0.14-0.74. Both the maximum swimming and maximum sustained speeds exhibited a good correlation with either body length or body weight, but not with the coefficient of fatness. The swimming ability indices of 24 species were in the range of 1.4-4.8. Regarding the temperature dependency of the swimming performance in 24 species, if the highest performance in these parameters was regarded as 100%, then the maximum swimming speed and the maximum sustained speed showed a range of 70-100% between the acclimation temperatures, and swimming

ability index showed a range of 65-100%. From these results, it was considered that the swimming performance of these species had a tendency to maintain a constant level within the acclimation temperatures. This research was supported by the Ministry of Economy, Trade and Industry.

**A2-6097**

## Spatial and temporal variability of chlorophyll *a* and their responses to marine environments in the South China Sea

Shan **Gao**[1], Hui Wang[2] and Liu Guimei[2]

[1] College of Environmental Science and Engineering, Ocean University of China, Songling Rd. 238, Laoshan District, Qingdao, 266100, PR China. E-mail: gaoshan_shining@163.com
[2] National Marine Environmental Forecasting Center, 8 Dahuisi, Haidian District, Beijing 100081, PR China

The dynamics of marine ecosystem are largely influenced by atmospheric and marine environmental conditions. In the South China Sea (SCS), the monsoon directly influences the ocean circulation and the mass transport processes, especially the changes of horizontal circulation pattern and upwelling area/intensity. These processes evoke changes in nutrient transport and of phytoplankton photosynthesis as evidenced by changes in chlorophyll *a* (Chl-*a*) distribution within different regions of the SCS. To understand the response dynamics of marine ecosystem to environmental factors, the present study analysed oceanographic (physical and biochemical) data to examine the spatial-temporal distributions of Chl-*a* concentration associated with marine environments for long periods in the SCS. The results indicated that seasonal and spatial distributions of Chl-*a* concentration in the SCS were primarily influenced by the monsoon winds and hydrography, particularly the spatiotemporal patterns of high Chl-*a* concentration in the region of summer upwelling off the east coast of Vietnam. Although inter-annual variability in phytoplankton distributions is not obvious in the SCS, the analysis revealed a significant, anomalously low phytoplankton biomass event in 1998. The study also presents a preliminary EOF analysis of remotely sensed data that assessed basic characteristics of the response process of Chl-*a* to physical changes in the SCS. Such research activities could be very important to gaining a mechanistic understanding of ecosystem responses to the climate change in the SCS.

**A2-6111**

## Population structure changes on size and age composition on Chilean hake (*Merluccius gayi gayi*) and their association with environmental conditions

Claudio Gatica[1], Claudio **Castillo-Jordán**[2], Sebastian Vasquez[1] and Rubén Alarcón[1]

[1] Instituto de Investigación Pesquera, Colón 2780, Talcahuano, Chile. E-mail: cgatica@inpesca.cl
[2] Laboratorio de Evaluación de Poblaciones Marinas (EPOMAR), Departamento de Oceanografía, Facultad de Ciencias Naturales y Oceanográficas, Universidad de Concepción, 4070423, Chile

The Chilean hake is one of the most important resources in the South-Central zone off Chile (34º00'S-41º00'S) with catches around 55 mil ton in the year 2009. This species is exploited by both artisanal and industrial fleets. Over the period 1992 to 2009, the population exhibited a strong decrease in abundance, particularly starting in 2002, which was attributed to the combined effects of increases in jumbo squid predation and fishery catches. The presence of jumbo squid is associated to oceanic warmer conditions and availability of prey (Chilean hake, jack mackerel and small pelagic). The analysis detected differences on the size and age composition in the catches and also in the population parameters estimated by direct and indirect assessment. Furthermore, age studies indicate that individuals within the present population have a smaller size-at-age than historically observed. This change in the population's structure is clearly apparent in the negative trend in the total length of individuals since 2002-2003. The proposed hypothesis is that the different sources of mortality have diminished the abundance of individuals with greater capacity for growth as characterized by high Loo (asymptotic length) and k parameters (growth coefficient).

**A2-6112**

## Annual trends in seasonal stock- and life-history-specific ocean migration of juvenile Chinook salmon *Oncorhynchus tshawytscha*: An application of genetic identification techniques

Strahan **Tucker**[1], Marc Trudel[1], David W. Welch[1,2], John R. Candy[1], John F.T. Morris[1], Mary E. Thiess[1], Colin Wallace[1] and Terry D. Beacham[1]

[1] Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
E-mail: Strahan.tucker@dfo-mpo.gc.ca
[2] Present address: Kintama Research Corporation, 4737 Vista View Crescent, Nanaimo, BC, V9V 1N8, Canada

Marine survival of salmon co-varies with climate and ocean conditions at both small and large spatial scales. Many factors could influence juvenile salmon movement and distribution, including large-scale oceanic transport and temperatures as well as the distribution of prey and predators. Juvenile (n=5973) and immature (n= 593) Chinook salmon were collected from coastal Washington to southeast Alaska in coastal trawl surveys from June to March 1998-2008. Large fluctuations were observed in ocean temperatures and in primary and secondary production during this decade. Using DNA stock identification, we reconstructed changes in stock composition for different years, seasons and regions. Individuals were allocated to 12 regional stocks. Most juvenile salmon, except those from the Columbia River, remained in relative close proximity to their natal rivers in their first year at sea, irrespective of smolt class. In contrast, Columbia River fish generally undertook a northward migration that varied among stocks and smolt class. Summer catches in all regions were dominated by Columbia River spring yearling fish suggesting rapid migration. In contrast very few Columbia River fall sub-yearling fish were recovered north of Vancouver Island. Columbia River salmon became minor components in catches in fall and winter as fish originating from other southern stocks dominated catches off Vancouver Island while northern British Columbia and Alaska stocks dominated northern regions during these time periods. Trends in proportional regional stock compositions were generally consistent between years suggesting migration patterns are fairly constant despite large fluctuations in ocean conditions.

**A2-6120**

## Behavioral response of Japanese amberjack, *Seriola quinqueradiata,* to sea water temperature rise caused by thermal effluent

Masao **Miura**[1], Toshiro Fujisawa[2], Hiroshi Yamada[3] and Takeya Hara[1]

[1] Central Laboratory, Marine Ecology Research Institute, 300 Iwawada, Onjukumachi, Isumigun, Chiba, 299-5105, Japan
E-mail: m-miura@kaiseiken.or.jp
[2] Former staff member of Marine Ecology Research Institute, Japan
[3] Demonstration Laboratory, Marine Ecology Research Institute, 4-7-17 Arahama, Kashiwazaki, Niigata, 945-0322, Japan

In order to obtain data to estimate the impacts of sea water temperature rise on the spatial distribution and migration of Japanese amberjack, *Seriola quinqueradiata*, field experiments using two large net pens (12m in diameter, 8-9 m deep) were conducted in waters around a nuclear power plant. One pen was set in the plume area, and the other (the control) was set outside of the plume. Increases ranging from 0 to 5°C were usually observed in the surface layer (0-4 m deep) inside the pen set in the plume area. Japanese amberjack kept in the pens showed clear behavioral responses, preference or avoidance, to water temperature. We estimated the preferred water temperature range by means of Jacobs' electivity index. The fish mainly swam in the surface warmer layer in which temperature was above 14°C in January and February, while they preferred the deeper layer in which temperature was below 28°C in August and September. The preferred temperature range was considered to change seasonally, and a positive correlation was found between the upper/lower limits of the preferred range and their habitat temperature measured in the control.

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**A2-6139**

## Seasonal lipid and fatty acids dynamics in *Leptoclinus maculatus* larvae from Svalbard waters in relation to abiotic and biotic factors

Svetlana A. **Murzina**[1], Stig Falk-Petersen[2], Jørgen Berge[3] and Nina N. Nemova[1]

[1] Institute of Biology, Karelian Research Centre RAS, Petrozavodsk, 185910, Russia. E-mail: imagination@onego.ru
[2] Norwegian Polar Institute, Tromsø, N-9296, Norway
[3] The University Centre in Svalbard, Longyearbyen, N-9171, Norway

*Leptoclinus maculatus* from the family Stichaeidae is a dominant and ecologically important fish species in Arctic waters that has a pelagic larva stage but is benthic as an adult. In the era of rapid climate change, the ecology of these important species and their role in the Arctic environment remains largely unstudied. Larvae feed on lipid-rich *Calanus* diet, and are thus a key prey species transferring lipid and energy from lower to higher trophic levels including predatory fish, sea birds and seals. We investigated the lipid and fatty acids profiles of flesh and lipid sac from larvae and juveniles *Leptoclinus maculatus* caught in summer (July) and winter (April) from two fjords – Isfjord, Kongsfjord and ice edge area at 80ºN Svalbard. Larvae were lipid rich and stored neutral lipids and their compounds predominantly in a lipid sac which they use for growth and development. Lipids stored in muscle/somatic tissue appear to provide energy for active movement in pelagic water layers and under ice cover. The fatty acid profile changed in relation to seasonal changes in diet, temperature of water and water currents.

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**A2-6142**

## Modeling the distribution and abundance of pelagic fish species as a function of environmental variables

Nandipha M. Twatwa, Dawit **Yemane** and Janet C. Coetzee

Marine and Coastal Management, Department of Environmental Affairs, Rogge Bay 8012, Private Bag X2, Cape Town, South Africa
E-mail: Ntwatwa@deat.gov.za

The densities of anchovy (*Engraulis capensis*), sardine (*Sardinops sagax*) and redeye (*Etrumeus whiteheadi*) in the southern Benguela system have never been linked to environmental fluctuations. Here, we explored the means by which environmental variability may be linked to changes in small pelagic fish abundance. Biomass estimates of these three small pelagic species off the coast of South Africa have been obtained annually by means of hydro-acoustic research surveys since 1984. Estimates of abundance obtained from these fishery-independent surveys are an essential part of the management of the South African pelagic resources. We used information collected adult spawning stock over 8-year period (2000-2007), together with environmental variables routinely collected during these surveys. We also looked at how the relationships change in response to fluctuations in the combined total biomass of these pelagic fish species over time. Results indicate that environmental preferences of small pelagic fish in the southern Benguela can be identified and quantified using GAMs. Abundance and distribution of small pelagic fish was different spatially and temporally, and supposedly temperature-driven. As the population declines, the majority of redeye remains on the west, mainly offshore on the south-western part while anchovy and sardine habitats tend to shrink along their traditional south-western (WAB) and offshore on the south, and rather become shifted eastwards. Our results suggest that the environmental dynamics may influence the spatial distribution and abundance of small pelagics in the southern Benguela ecosystem. This study is expected to contribute towards understanding the likely impact of climate change on small pelagic.

## A2-6160

## Environmental impacts on long-term variation in recruitment success of Japanese sardine

Haruka **Nishikawa**[1], Ichiro Yasuda[1], Sachihiko Itoh[1], Hideharu Sasaki[2] and Yoshikazu Sasai[3]

[1] Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 1648639, Japan
E-mail: harukan@ori.u-tokyo.ac.jp
[2] Japan Agency Marine Earth Science and Technology, Earth Simulator Ctr., Kanazawa-ku, Yokohama, Kanagawa, 2360001, Japan
[3] Japan Agcy Marine Earth Science and Technology, Frontier Res. Ctr. Global Change, Kanazawa-ku, Yokohama, Kanagawa, 2360001, Japan

A drastic population change in Japanese sardine, *Sardinops melanostictus*, has been related to environmental indices, for example, sea surface temperature (SST) or mixed layer depth (MLD) in the Kuroshio Extension region, downstream from spawning grounds in the south of Japan. In the present study, outputs of a highly spatially- and temporally-resolved general ocean circulation model OFES were used to detect environmental fluctuations around the Kuroshio and its extension, which could not properly be assessed in previous studies due to the high variability in the path and structure of the flow. Stream coordinate analysis from 1951 to 2006 revealed that SST and winter MLD in the narrow frontal zone along the Kuroshio were significantly related to Japanese sardine recruitment: recruitment rates are high in the cool SST and deep MLD period and low in the warm SST and shallow MLD period. The importance of the frontal zone was supported by particle tracking experiments performed on sardine spawning grounds, as significant amounts of eggs and larvae were simulated to be transported there for most of the years. This frontal zone is highly productive and the production depends on the nutrients supplied through deep winter mixed layer. These results suggest that interannual variation in winter MLD along the Kuroshio axis and consequent fluctuation in food availability is responsible for the drastic fluctuations in the stock productivity of Japanese sardine.

## A2-6161

## Comparing the influence of oceanographic fronts on interannual changes in the distribution and relative abundance of sardine in the California and Southern Benguela Current systems

Rubén **Rodríguez-Sánchez**[1], Carl van der Lingen[2], Marlene Manzano[3], Larry Hutchings[2] and Héctor Villalobos[1]

[1] Centro Interdisciplinario de Ciencias Marinas (CICIMAR - I.P.N.), Apartado Postal 592, La Paz, B.C.S., C.P. 23090, México
E-mail: rrodrig@ipn.mx
[2] Marine and Coastal Management (MCM), Private Bag X2, Rogge Bay 8012, South Africa
[3] Facultad de Ciencias del Mar, Universidad Autónoma de Sinaloa, Paseo Claussen s/n, Mazatlán, Sinaloa, México

Marked changes in the distribution and relative abundance of sardine *Sardinops sagax* populations in the California and Southern Benguela Current systems have been reported (CCS and SBCS, respectively), with these changes occurring over recent decades during periods of steadily increasing population size in both systems. Such distributional changes may be environmentally-mediated. We assess whether mesoscale frontal activity could be a mechanism underlying latitudinal and longitudinal shifts in sardine distribution in CCS and SBCS, respectively. Over the period 1980-1997 sardine in the CCS showed a progressive northward shift in the location of highest relative abundance, suggesting northward changes in the location of favorable conditions for young sardines along the frontal zone where the southward California Current and the inshore, poleward California Countercurrent (CcC) converge. We proxied interannual variability along the frontal zone by developing monthly time-series of the frequency of SST fronts in different areas along the California–Baja California coast using the single-image, edge-detection method applied to monthly satellite data. The relationship between sardine abundance and SST front frequency indices suggests that recruitment increases where optimal front-frequency levels are found and declines where they are suboptimal. We use a similar approach to assess whether the eastward shift in the distribution of Southern Benguela sardine was also environmentally mediated by examining frontal activity data in the period 1985-2005, from different areas along the Agulhas Bank, where seasonal and interannual variation in interactions between a major surface boundary current (the westward-flowing Agulhas Current) and an eastward-moving, coastal counter-current also occur.

**A2-6187**

## Relationship between environmental variability and distribution of common squid (*Todarodes pacificus*) paralarvae in the northern East China Sea

Jung Jin **Kim** and Suam Kim

Department of Marine Biology, Pukyong National University, Busan, 608-737, R Korea. E-mail: theocean81@hotmail.com

Understanding factors affecting the processes impacting the transport and distribution of early life stages is essential for the ability to make robust predictions of year-class strength of marine species. To reveal the transport process pattern of common squid (*Todarodes pacificus*) paralarvae, we carried out ichthyoplankton surveys using Bongo nets in the northern East China Sea during July 2006-2008. Most paralarvae were captured in the southeastern Jeju Island and the north of Kyushu Island where water temperatures at 50 m ranged from 15 to 20°C and salinities were 33 to 34 psu. Based on re-analysis of climate information, Regional Ocean Modeling System (ROMS) was used to track transport routes of eggs and paralarvae into the sampling region. Results from particle tracking experiments indicated that paralarvae produced in the spawning area (*i.e.*, southern East China Sea) would require a drifting period of 10 to 30 days to reach the sampling region, with drift duration influencing recruit success in the following year. We also examined the relationship between paralarvae distribution and ocean environmental characteristics such as the expansion of low salinity water from the Changjiang River, annual variation in the strength of Tsushima Warm Current, temporal and spatial distribution of chlorophyll *a* concentrations, and climate variability in the study area.

**A2-6200**

## Are crustacean landings from Portuguese waters driven by environment variables?

Ana **Moreira**, Paulo Fonseca, Cristina Silva, Aida Campos, Maria de Fátima Borges and Miguel Santos

INRB/IPIMAR, Portuguese Institute for Fisheries Research, Av. de Brasilia, 1449-006, Lisboa, Portugal. E-mail: moreiratrue@gmail.com

Crustaceans constitute a highly valuable component of the Portuguese continental bottom trawling fisheries and are currently targeted by about 30 vessels. The fishery is carried out mainly off the south and, to a lesser extent, the south-western coasts, at depths ranging from about 150 to more than 600 metres depending upon the target species. Target species include Norway lobster (*Nephrops norvegicus*) a benthic burrowing species, and several benthopelagic shrimps including deepwater red shrimps (*Aristeus antennatus, Aristeomorpha foliacea, Aristaeopsis edwardsiana*) and the shallow water rose shrimp (*Parapenaeus longirostris*) but the fishery is mainly constituted by catches of Norway lobster and rose shrimp. During a 23-yr period (from 1986 through 2008), the landings of both species were highly variable, with that of rose shrimp being particularly striking (*e.g.*, 800 to 2000 tons in 1998 and 1990 or 1000 to about 140 tons between 2003 and 2004). The fact that the different species may be (and often are) captured during the same fishing trip makes it difficult to correctly attribute the true effort exerted on each of them. The latter adds a further level of complexity when trying to disentangle fisheries-induced from environment-induced fluctuations in landings. In that regard, rose shrimp may be considered as a pivotal species since fishers reorient their effort towards the other main target species (Norway lobster) depending upon fluctuations in the abundance of rose shrimp. In the present study, we examined whether the landings of both Norway lobster and rose shrimp from 1986 until 2008 were correlated with environmental variables such as the winter NAO (North Atlantic Oscillation) and upwelling indexes, local sea surface temperature and rainfall, and runoff from major rivers to explore the potential factors underpinning the recruitment variability in these species as evidenced by the marked fluctuations in abundance and subsequent landings.

**A2-6217**

## Climate change impacts on the ocean distributions of Pacific salmon

Omar I. **Abdul-Aziz** and Nathan J. Mantua

Climate Impacts Group, Joint Institute for the Study of Atmosphere and Ocean, and School of Aquatic and Fishery Sciences, University of Washington, 1122 Boat St., Seattle, WA, 98195-5020, USA. Email: omaraziz@u.washington.edu

The ocean distributions of Pacific salmon (*Oncorhynchus* spp.) are strongly related to sea surface temperatures (SSTs). Over 50 years of high-seas surveys indicate that major salmon species are surface oriented, spending most of their time at depth <40m. Since anthropogenic climate change is predicted to increase SSTs in the 21st century, climate change will likely impact the distribution, growth, survival, abundance, and productivity of Pacific salmon. This research used observed thermal limits for Pacific salmon to evaluate the impacts of past and projected future SST changes on the high-seas habitat amount and distribution of Pacific salmon. We defined reference summer and winter thermal habitats for sockeye (*O. nerka*), chum (*O. keta*), pink (*O. gorbuscha*), coho (*O. kisutch),* chinook (*O. tshawytscha*), and steelhead (*O. mykiss*) salmon. Time-averaged mean monthly SST data from 18 major global climate models (GCMs) for the 20th and 21st centuries are regridded to a reference resolution and corrected for biases comparing with historical observations. Historical ocean thermal habitat areas and distributions are analyzed and mapped considering the warm and cool phases of Pacific Decadal Oscillation (PDO) to evaluate the impacts of natural inter-decadal climate variability. Potential future changes are quantified under three scenarios of lower (B1), medium (A1B), and higher (A2) greenhouse gas emissions. Results reveal that changes in 20th century were within a few percent of historical references. In contrast, much larger reductions of salmon distributions are projected in both summer and winter seasons by middle through the end of the 21st century.

**A2-6224**

## Geographic variation in Pacific herring growth and population responses to regime shifts in the North Pacific basin

Bernard A. **Megrey**[1], Kenneth A. Rose[2], Jacob F. Schweigert[3], Douglas Hay[3], Francisco E. Werner[4], Yasuhiro Yamanaka[5] and Shin-ichi Ito[6]

1 NOAA, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way, NE, WA, 98115, USA
E-mail: bern.megrey@noaa.gov
2 Department of Oceanography and Coastal Sciences, and Coastal Fisheries Institute, Louisiana State University, Baton Rouge, LA, 70803, USA
3 Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC, V9R 5K6, Canada
4 Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ, 08901, USA
5 Graduate School of Environmental Earth Science, Hokkaido University, N10W5 Kita-ku, Sapporo, Hokkaido, 060-0810, Japan
6 Tohoku National Fisheries Research Institute, 3-27-5 Shinhama-cho, Shiogama, Miyagi, 985-0001, Japan

Pacific herring populations at eight Pacific Rim locations were examined for basin-wide geographic variations in growth due to environmental influences on marine productivity and population-specific responses to regime shifts. Temperature and zooplankton abundance from a 3D-NEMURO simulation model of lower trophic level NPZ dynamics from 1948 to 2002 was used as input to a herring bioenergetics growth model. Herring populations from the California Current, West Coast Vancouver Island, Prince William Sound, Togiak Alaska, western Bering Sea, Sea of Okhotsk, Sakhalin, and Peter the Great Bay were examined. Changes in age-5 herring wet weight were used to compare the stocks. We applied the sequential t-test analysis to detect regime shifts in simulated temperatures, zooplankton and herring growth rates to identify statistical shifts in their average values. We explored spatial relationships using cluster and principal component analyses. Populations were compared among locations to determine if herring responses were consistent. Results from cluster analyses indicate close spatial associations among herring populations from adjacent ecosystems. Spatial associations were less evident in the temperature and zooplankton data series. The regime shifts analyses showed an inverse relationship between temperature and zooplankton abundance, and evidence of bottom-up control on herring growth patterns. Principal component analyses also revealed regime shift patterns and, for some variables, showed opposite loadings for the western *vs.* the eastern Pacific basin locations. Implications of these results are discussed with respect to the range of responses to climate variation or change that can be expected from a single, pan Pacific species.

**A2-6246**

## Northern *vs*. southern European Seas: Investigating spatio-temporal patterns of *Mullus surmuletus* distribution in relation to environmental changes

Christos D. **Maravelias**[1] and Alex Tidd[2]

[1] Hellenic Centre for Marine Research (HCMR), 46.7 km Athens-Sounio Ave., 19013 Anavyssos, Greece
E-mail: cmaravel@ath.hcmr.gr
[2] Centre for the Environment, Fisheries and Aquaculture Science (CEFAS)

Two diametrical regional seas of Europe, the North Sea and the Aegean Sea, have both shown increases in mean bottom sea water temperature during the mid 1990s, which appear to be part of the global warming trend rather than a local phenomenon. The present study analyses the changes in both spatial and temporal variability of red mullet *Mullus surmuletus*, an increasingly important commercial demersal fish, in response to the observed climatic trends. Commercial demersal trawler time series of species production (landings) was further investigated to examine whether the landings have been affected by the climatic changes (water warming). Analyses of catch data suggest distinct shifts in the pattern of distribution and habitat use of red mullet in European waters. The observed changes in the spatial aggregation of the species are discussed in the light of effects on fisheries and management strategies.

**A2-6251**

## Recruitment and migration of Pacific cod (*Gadus macrocephalus*) to southern Korean coastal waters in relation to variations in the bottom cold waters originating from the Japan/East Sea

Sukgeun **Jung**

National Fisheries Research and Development Institute, 408-1 Sirang-ri, Gijang-eup, Gijang-gun, Busan, 619-902, R Korea
E-mail: Sukgeun.jung@gmail.com

The two Gadoid species, Pacific cod (*Gadus macrocephalus*) and Alaska pollock (*Thergra chalcogramma*), have been traditionally important commercial fish species in the Japan/East Sea. In Korean coastal waters, global warming has apparently increased sea surface temperatures by ca. 1°C during the past 40 years whereas bottom temperatures have not significantly increased. However, since the late 1990s, bottom temperatures in the southern Korean coastal waters during the winter spawning season have significantly decreased, probably related with strengthened mixed layers and increased frequency of cold-water penetration from the Japan/East Sea. I speculate the decreased bottom temperatures favor the recruitment of Pacific cod (*Gadus macrocephalus*) whose eggs are demersal and hatch at 5-12°C. Recruitment of cod seemed to decrease from the 1950s to the 1990s, as catch levels were lower compared with the 1920-1940s. Since 1998, however, catch has continued to increase from 0.5 x $10^3$ metric tons in 1998 to 7.2 x $10^3$ tons in 2007, reaching a record high. In addition to the temperature changes, annual catch of Pacific herring (*Clupea pallasii*), an important dietary component for Pacific cod, also has dramatically increased from 1.9 x $10^3$ tons in 2002 to 43.8 x $10^3$ tons in 2008, indicating that bottom-up control by Pacific herring and zooplankton also could have helped recruitment of Pacific cod in Korean coastal waters. I am currently investigating the relationship of recruitment and migration of cod, pollock and herring with respect to variations in the Tsushima warm current and bottom cold waters in the Korea Strait.

**A2-6254**

## Contrasting responses in larval and juvenile growth rates of anchovy and sardine to a climate-ocean regime shift: Implications for their population dynamics

Motomitsu **Takahashi**[1], Yoshiro Watanabe[2], Akihiko Yatsu[1] and Hiroshi Nishida[3]

1 Seikai National Fisheries Research Institute, Fisheries Research Agency, 1551-8 Taira-machi, Nagasaki, Nagasaki, 851-2213, Japan E-mail: takahamt@fra.affrc.go.jp
2 Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
3 National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa-ku, Yokohama, Kanagawa, 236-8648, Japan

We examined variability in growth rates during early life stages for Japanese anchovy and sardine in response to a climate-ocean regime shift in the late 1990s in the western North Pacific. Late larval and early juvenile anchovy and sardine were collected in the Kuroshio-Oyashio transitional waters using a subsurface trawl net in May-June during 1996-2002. Growth rates during the larval and early juvenile stages were backcalculated using otolith daily increments for both species. Our previous studies in the transitional waters demonstrated that the abundance of age-0 recruits was a positive function of the growth rates. Decline of the sardine growth rates and increase of the anchovy growth rates occurred simultaneously after 1999 with increase in temperature in the transitional waters. Growth-environment analysis revealed that increased temperature enhanced anchovy growth rate, but reduced prey concentrations diminished sardine growth rate. The Kuroshio Extension (KE) was intensified and the position of the KE shifted northward during the survey period. When sardine population began to collapse and anchovy tended to flourish in the late 1980s, the KE was strengthened and shifted northward similar to what happened in the late 1990s. When sardine population began to expand and anchovy shrank in the early 1970s, the KE weakened, contrary to the late 1990s. Our results suggest that contrasting responses in growth and survival processes to decadal changes in states of the KE caused the replacement of dominant species for small pelagic fishes, anchovy and sardine, in the western North Pacific.

**A2-6255**

## An investigation of the relationship between bigeye tuna (*Thunnus obesus*) catch and three dimensional thermal structures

Akiko **Takano**[1], Hidekatsu Yamazaki[1], Osamu Honda[2], Kotaro Yokawa[3] and Hiroshi Shono[3]

1 Laboratory of Ocean Ecosystem Dynamics, Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato-ku, Tokyo, 108-8477, Japan. E-mail: takanoa@affrc.go.jp
2 Japan Fisheries Information Service Center, Tokyo, 104-0055, Japan
3 National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Shizuoka, 424-8633, Japan

We have examined how subsurface thermal structures affect the distribution and abundance of bigeye tuna (*Thunnus obesus*) caught by Japanese surface longliners. The longliners operated in the Kuroshio Extension (KE) area throughout the year to target swordfish and blue shark, and bigeye tuna is one of their secondary target species. Our analyses indicated that the annual fluctuation of bigeye tuna catch from 2004 to 2007 was too large to be attributed solely to annual changes in abundance, especially in winter. Analysis of the thermal structure at each operational point indicated that the highest catches were located in areas where the 15°C isothermal depths were around 200 – 280 m, west of Shatsky rise in winter. Similar thermal structures also occurred in the KE fronts or at the edge of warm-core rings (WCR) that had been pinched off from the KE meanders. High correlations were observed between the abundance of bigeye tuna in catches and the number of sets deployed within areas where the thermal structure was expected to be good for the catch. The result of this study strongly indicated that longline catch of bigeye tuna in winter was affected by the thermal structure and identified the thermal signature of water masses inhabited by this species during the daytime.

**A2-6260**

## Effects of climate variability on the distribution, abundance and habitat usage of juvenile salmonids in the coastal waters of the northern California Current

Cheryl A. **Morgan**[1], William T. Peterson[2], Joseph P. Fisher[3] and Jesse F. Lamb[3]

[1] Cooperative Institute for Marine Resources Studies, Oregon State University, Hatfield Marine Science Center, 2030 South Marine Science Dr., Newport, OR, 97365, USA. E-mail: cheryl.morgan@oregonstate.edu
[2] NOAA Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, 2030 South Marine Science Dr., Newport, OR, 97365, USA
[3] Cooperative Institute for Marine Resources Studies, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR, 97331, USA

Each June and September from 1998 until present, hydrographic, plankton, and juvenile salmon surveys are conducted off Oregon and Washington, USA along 8 transect lines between 44.6° and 48°N latitude, with stations ranging from 2 to 60 km offshore. During the study period, large shifts in the physical and biological conditions in the northern California current occurred, including the 1997/98 El Niño, the 1999 La Niña, positive and negative values of the PDO, and years of strongly contrasting upwelling intensity. These varying conditions provide insights into how abundances, distribution, survival and habitat usage of Chinook and coho salmon may change in response to climate changes. Abundances of Chinook and coho salmon were significantly correlated with water depth (negatively), chlorophyll (positively) and copepod biomass (positively). Abundances of yearling and sub-yearling Chinook salmon, but not yearling coho salmon, were correlated with temperature (negatively). Abundances are higher during years when the PDO was negative. The strength of coastal upwelling in June influences the offshore extent of salmonid distributions – when upwelling is strong the fish are found at greater the distance offshore; no correlation was found between upwelling strength and fish distribution in September when upwelling is weak-to-nonexistent. The optimal physical habitat parameters seem to be strong upwelling, high chlorophyll concentrations, and a boreal copepod community each of which is influenced by the PDO. Climate change scenarios that include a weakening of the PDO or of upwelling strength, suggest a negative impact on salmon.

**A2-6270**

## Changes in the life history traits of Japanese anchovy and sardine

Yuu **Katsukawa**[1], Yoshiro Watanabe[1], Hiroshi Okamura[2], Tatsuya Suzuki[3] and Hisashi Nakategawa[4]

[1] Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakanoku, Tokyo, 164-8639, Japan. E-mail: yu@ori.u-tokyo.ac.jp
[2] National Research Institute of Far Seas Fisheries, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa 236-8648, Japan
[3] Chiba Prefectural Fisheries Technology Research Center, 2492 Hiraiso, Chikura, Minamiboso, Chiba, 295-0024, Japan
[4] Kanagawa Prefectural Fisheries Technology Center, Jyogajima, Misaki, Miura, Kanagawa, 238-0237, Japan

When environmental conditions vary, fitness benefit accrues to individuals from the changes of life history. The changes of life history affect the vital rates and population dynamics. Japanese anchovy (*Engraulis japonicus*) and Japanese sardine (*Sardinops melanostictus*) were documented long-term fluctuations in abundance. As yet, time series data of life history traits are lacking and trends reported only in fragments. Moreover, it has not yet been explored how changes of life history influence the population dynamics. In this study, we evaluate how changes in life history traits (*e.g*. body size, body condition and reproductive investment) for Japanese anchovy and sardine. Pacific stock of anchovy and sardine were divided into three sub populations (northern, middle and southern population). We described trends in the indices for individual stocks and compared characteristic of stocks. We then examine whether trends in the indices are thought to be the response to the population density. In addition, we predict the changes of vital rates using parameter of growth and maturation. Time series data (body length, body weight, gonad weight, sex, and date of capture) from 1960s to 2000s in the Pacific stocks of Japanese anchovy and sardine were obtained. We compiled data from various agencies. In the 1980s, the body length and body weight of Japanese sardine decreased, but the age at maturation increased. Because the growth rate decreased in 1980s, the sexual maturation delayed. Life history traits of Japanese sardine compensatorily responded to abundance changes, whereas those of Japanese anchovy responded differently with its abundance changes.

**A2-6280**

## The rise and fall of snake pipefish (*Entelurus aequoreus* L.) off North Scotland

Jörn O. **Schmidt** and Rüdiger Voss

Sustainable Fishery, Department of Economics, University of Kiel, Wilhelm-Seelig-Platz 1, Kiel, 24118, Germany
E-mail: jschmidt@ifm-geomar.de

Global change, especially the warming of seawater, has led to the observation of changing distributions of fish species in the past decades. The last decade has seen an unprecedented increase in snake pipefish (*Entelurus aequoreus* L.) off the British Northern coasts and the North Sea. Well documented from larval and trawl surveys as well as from reports of fishermen and the interested public, this increase was suspected to be caused by increasing water temperatures. We add information from the international herring larval survey (IHLS), which is performed yearly in September in the area of the Orkney and Shetland Isles, on larval abundance of snake pipefish. The dramatic increase of larval snake pipefish was seen from 2002 onwards. A peak in 2005 was then followed by a steep decrease and near zero abundance in 2008. Recent, anecdotal reports from several locations at the British North East coast also state a decrease of snake pipefish. Thus the question arises, if the snake pipefish "outbreak" is over and what was its cause? The interesting point is that the environment has not changed again, thus an internal reason or a single event seem to be the cause of the sudden increase. Decadal fluctuations could, at least from the available dataset (1984 – 2008), not be seen.

**A2-6314 (*Cancelled*)**

## Warming influences productivity of lobster stocks in SE Australia

Caleb Gardner and Stewart **Frusher**

Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Private Bag 49, Hobart, Tasmania, Australia, 7001
E-mail: stewart.frusher@utas.edu.au

Nestled at the interface of three water masses in southern Australia, the southern rock lobster *Jasus edwardsii,* is subject to changes in temperature as these water masses alter in their dynamics. By using a 16 year mark recapture dataset we are able to link temperature changes to growth in two different regions that are influenced to different extents by these water masses. These changes, which influence both growth and reproduction, are discussed in relation to predicted temperature increases and its impact on assessment of the fishery.

**A2-6317**

## Contrasting ecological responses of two commercially important finfish to severe tropical cyclones: A sullen serranid and a lively lethrinid

Andrew **Tobin**[1], Audrey Schlaff, Besse Krause, David W. Welch, Tony Ayling, Hugh Sweatman, Paul Marshall, Brigid Kerrigan and Jeff Maynard

[1] Fishing and Fisheries Research Centre, James Cook University, Townsville, 4811, Australia. E-mail: andrew.tobin@jcu.edu.au

With climate change scenarios predicting more severe tropical cyclones (TCs), understanding the effects of these storms on fisheries productivity is mandatory. A long-term commercial fishery data set has been explored to describe the ecological response of a serranid (*Plectropomus leopardus*) and lethrinid (*Lethrinus miniatus*) to severe TCs. The two species dominate catches from a commercial line fishery operating within the Great Barrier Reef (GBR), northeastern Australia. Between 1994 and 2009, two TC events (from a total of 12) caused significant though starkly contrasting behavioral responses in *P. leopardus* and *L. miniatus*. In March 1997, the long-lived (24 day) category 2 TC Justin caused mild reef damage but significant water cooling. In March 2009 the short-lived (5 day) category 5 TC Hamish, caused wide-spread structural damage though little change in water temperatures. The contrasting response of both fish species was consistent between these TC events even though both events were vastly different. *P. leopardus* became significantly less frequent in catches while *L. miniatus*

became more prevalent, particularly within the mid-section of the GBR. These responses were long lasting and challenging, as live export of *P. leopardus* is the main stay of economic profitability. With the threat of increasing storm severity, it is mandatory to understand both the immediate and lagging effects of these events. Of equal importance is the need to consider how best to equip managers and fishers with tools appropriate for mitigating the negative effects associated with severe weather events when they occur.

**A2-6319**

## Are geographically distinct populations similarly impacted by ocean acidification? (Oysters as a case study)

Haruko **Kurihara**[1], Yuji Hiratsuka[1], Takamasa Asai[2], Atsushi Ishimatsu[2], Laura Parker[3] and Pauline Ross[3]

[1] Transdisciplinary Research Organization for Subtropical Island Studies, University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa, 903-0213, Japan. E-mail: harukoku@e-mail.jp
[2] Institute for East China Sea Research, Nagasaki University, 1551-7 Tairamachi, Nagasaki, 851-2213, Japan
[3] School of Natural Sciences, College of Health and Science, University of Western Sydney, Penrith South DC1797, Sydney, NSW, Australia

An extensive number of studies have evaluated the effects of ocean acidification on marine organisms, finding in general, negative impacts on several different marine calcifiers. Most of these studies, however, have dealt with a single species, in a single population in a single geographic region. Since geographically distinct populations may vary genetically from each other and experience different environment conditions, their responses to ocean acidification have a potential to differ between populations. Indeed, coccolithophores have been found to respond to high $CO_2$ depending on the distinct strain under investigation; although the methodological difference between studies makes the interpretation of the results difficult. Additionally, several other studies conducted to determine the effect of ocean acidification on commercially important marine shellfishes have used aquafarming organisms, which may vary in response to the natural population. Accordingly, here we measure if geographically distinct populations within Japan and between Australian and Japan responded to ocean acidification ($CO_2$ 1,000ppm, pH 7.8) at the fertilization and veliger larval stages of *Crassostrea gigas* (Pacific oysters). Three natural (Nagasaki, Hiroshima, Aomori) and three aquafarming (Nagasaki, Hiroshima, Miyagi) Japanese populations and one aquafarming oyster population from Australia (Port Stephens, NSW) of *C. gigas* were used. Here we found for the first time that the responses to ocean acidification can differ between distinct populations.

**A2-6331**

## Metamorphosis is closely associated with condition factor in Japanese anchovy in the Pacific coast waters of central Japan

Kinuyo Fukamichi, Yoshiro **Watanabe**, Isamu Mitani and Tomohiko Kawamura

Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakanoku, Tokyo, 164-8639, Japan
E-mail: ywatanab@ori.u-tokyo.ac.jp

Body length composition of commercial catches of late larval Japanese anchovy (*Engraulis japonicus*) has been known to vary seasonally in Sagami Bay on the Pacific coast of central Japan. This implies that size-at-metamorphosis from larval to juvenile stage seasonally changes probably depending on seasonal change in temperature and other environment factors in the Bay. We collected late larval anchovy 2-3 times a month from March 2008 to September 2009 and assigned them to early and late metamorphosing stages by examining deposition of guanine on the body. Standard length (L) of metamorphosing larvae changed seasonally, being small in summer and large in winter. Condition factor (C) of larvae changed seasonally as well, high in summer and low in winter, but C of metamorphosing larvae was nearly constant through seasons. Midpoint C of metamorphosing larvae was about 7.3, which may be defined as a threshold of C for metamorphosis of larvae to the juvenile stage. As growth in body weight relative to body length was faster in summer than in other seasons, larvae attain threshold C of 7.3 at a smaller SL in summer than in the other three seasons. Seasonal growth rate change in body weight relative to body length (= C) seems to be a factor regulating size-at-metamorphosis in Japanese anchovy.

**A2-6334**

## Comparative reproductive ecology of Japanese anchovy, *Engraulis japonicus*, in different current areas off Japan

Mika **Suhara**[1], Yoshiro Watanabe[1], Yuu Katsukawa[1], Yasuo Mori[2], Satoshi Katayama[3], Masayuki Yamamoto[4] and Tomohiko Kawamura[1]

1 Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
E-mail: suhara@ori.u-tokyo.ac.jp
2 Kushiro Fisheries Experiment Station, 2-6 Hamamachi, Kushiro, 085-0024, Japan
3 National Research Institute of Fisheries Science, 6-31-1 Nagai, Yokosuka, 238-0316, Japan
4 Kagawa Fisheries Experiment Station, 75-5 Yashima-higasicho, Takamatsu, 761-0111, Japan

The Japanese anchovy population increased in the 1990s with the climate-ocean regime shift in the late 1980s. With the population increase, their spawning grounds expanded from the subtropical Kuroshio Current (KC) to the subarctic Oyashio Current (OC) areas. We compared standard length (SL), gonadosomatic index (GSI), and condition factor (CF) of adult anchovy among OC, KC and its branch of Tsushima Current (TC) areas and discussed differences in reproductive ecology of anchovy among the areas. The mature anchovy were collected in spring and summer from the three current (OC, KC, TC) areas. In early summer, SL, GSI and CF were largest in OC area among the three areas. SL and GSI decreased in all areas in late summer. CF greatly decreased in OC area from early (14.1 ± 1.2) to late summer (9.8 ± 0.8), but stayed at a relatively high level in KC (11.2 ± 1.0) and TC (10.5 ± 1.5) areas. GSI decreased in all areas in late summer, most remarkably from in OC area from 7.4±2.7 to 0.3±0.2 compared to KC area from 4.4±1.5 to 1.4±1.3 and in TC from 1.6±1.6 to 1.1±2.0. This study found that anchovy had more concentrated spawning activity in summer in the OC area compared to a prolonged spawning season in KC and TC areas.

**A2-6343**

## Influence of environmental factors on the distributions of Pacific saury in the northwestern Pacific Ocean

Chen-Te **Tseng**[1,2], Chi-Lu Sun[2], Su-Zan Yeh[2], Shih-Chin Chen[1] and Wei-Cheng Su[1]

1 Fisheries Research Institute, Keelung, 202, Taiwan, ROC. E-mail:cttseng@mail.tfrin.gov.tw
2 Institute of Oceanography, National Taiwan University, Taipei, 106, Taiwan, ROC

The logbook data of 2006-2008 Taiwanese Pacific saury fishery in the northwestern Pacific Ocean and the MODIS satellite-derived sea surface temperature (SST) data of the same period were analyzed to explore the relationship between the saury fishing grounds and the SST fronts extracted using an edge-detection histogram based on the Cayula-Cornillon algorithm. Results showed that catch per unit effort (CPUE) of the saury fishery was at an average of 18.5 metric tons/day/boat and the fishing grounds concentrated in 38-49°N latitude and 143-162°E longitude. The major fishing season was from September to December and there was an evident monthly variation in fishing gravity. Results indicated that higher CPUE had shorter distance to SST fronts, there exists a negative linear relationship ($R^2$=0.14) between the CPUEs and SST fronts. In addition, the satellite-derived sea surface height anomaly (SSHA) and its derivative geostrophic current were used to identify the cold-core eddies (*i.e.* enclosed areas with SSHA less than -25 cm) and warm-core eddies (enclosed areas with SSHA greater than 15 cm). Results showed that the Kuroshio warm-core eddies usually intruded into Oyashio current to affect the spatial and temporal distributions of Pacific saury catches. Fewer warm-core eddies were found during June to August when CPUEs were low (9.7 metric tons/day/boat), while increasing twice the warm-core eddies increased the CPUEs up to 19.5 metric tons/day/boat during September to December. A negative linear relationship ($R^2$=0.35) was found between the CPUE of Pacific saury and its distances to those warm eddies.

**A2-6350**

## Ocean temperature, cod stock distribution and cod fisheries in the Barents Sea the last decades

Cecilie **Kvamme**, Geir Odd Johansen, Jan Erik Stiansen, Trond Westgard, Bjørn Adlandsvik and Sigrid Lind Johansen

Institute of Marine Research, P.O. Box 1870 Nordnes, Bergen, N-5817, Norway. E-mail: cecilie.kvamme@imr.no

Climate changes, through increased ocean temperature, are known to influence geographical distributions of fish stocks in several marine ecosystems. This may further inflict changes in the distribution of fisheries in time and space. The northeast Arctic cod (*Gadus morhua*) stock in the Barents Sea is currently the largest cod stock in the world. In the present study we analyse the historical relationships between ocean temperature in a specified layer above the sea floor, the geographical distribution of the cod stock based on bottom trawl indices from research vessel surveys, and cod catches from fishing logbooks in the period 1980-2008. The data are taken from a database for the Barents Sea and adjacent areas that joins hydrographic (temperature and salinity), scientific survey, and fisheries data in a common spatial and temporal grid. Different spatial distribution parameters are used to describe the spatial dynamics in distribution of fish and catches. This is related to year-to-year variation and time trends in ocean temperature, distribution of prey species, and cod abundance.

**A2-6377**

## Patterns in a changing climate: Fine-scale analysis of arrowtooth flounder catch rates in the eastern Bering Sea reveals spatial trends in abundance and diet

Stephani **Zador** and Kerim Aydin

NOAA Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115, USA. E-mail: stephani.zador@noaa.gov

Multiple lines of evidence suggest that changes in the marine climate in the Bering Sea are leading to numerical and distributional shifts in fish populations. Arrowtooth flounder (*Atherestheses stomias*) have quadrupled since the early 1980s in the eastern Bering Sea. Recently, recommended catches for walleye pollock (*Therega chalcogramma*) have been reduced, in part due to concerns about the growing threat of arrowtooth flounder predation of juvenile pollock. Thus, the goal of our study was to improve our understanding of the impact of arrowtooth flounder to commercial fisheries in the changing climate of the Bering Sea. We found that small-scale regions within the eastern Bering Sea shelf have contributed unequally to the overall rapid increase in abundance of arrowtooth flounder. Hierarchical k-medoids clustering of arrowtooth catch-per-unit-effort revealed four distinct spatial groups showing stable, increasing, and variable trends. Catch rates in high-density areas near the shelf break have remained stable since the early 1990s while catch rates have increased to the northwest and east. Annual changes in range expansion and contraction are negatively correlated with the extent of the cold water pool on the shelf. Age-1 and -2 pollock comprise the majority of arrowtooth diets in all areas, but higher rates of non-empty stomachs in the northwest region indicate that predatory impacts on pollock may be higher there. This analysis will provide information about the potential for arrowtooth flounder to further increase their distribution and abundance in the Bering Sea and help to predict future responses to climate and fisheries management actions.

# B1 Oral Presentations

**27 April, 9:05 (B1-6053), Invited**

## Possible trends in North Pacific ecosystems over the 21st century based on output from a coupled climate, biogeochemical, and phytoplankton model

Jeffrey J. **Polovina**[1], John P. Dunne[2], Phoebe Woodworth[3] and Evan A. Howell[1]

1 NOAA Pacific Islands Fisheries Science Center, Honolulu, HI, USA. E-mail: Jeffrey.Polovina@noaa.gov
2 NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA
3 Joint Institute of Marine and Atmospheric Science, University of Hawaii, Honolulu, HI, USA

Output from the NOAA Geophysical Fluid Dynamics Laboratory's Earth System Model (ESM2.1) that includes a biogeochemical and ocean phytoplankton model run under the A2 greenhouse gases forcing scenario was used to explore possible North Pacific ecosystem changes. The model output included a suite of physical, chemical, and phytoplankton variables aggregated monthly from 1998-2100 with a spatial resolution ranging from 1 degree at high latitudes to 1/3 degree at the equator. Model phytoplankton density was used to define subarctic, subtropical, and eastern tropical Pacific biomes and to examine how the area, phytoplankton density, phytoplankton species composition, and primary production of these biomes changed over time. A key model result was that by the end of the 21st century, the area of subtropical biome is 24% larger while the subarctic and eastern tropical Pacific biomes are both 27% smaller. Further, with warming occurring within each biome, cooler thermal habitats shrink or vanish while warmer ones expand or are created. For example, the area of sea surface temperature SST 30 °C and warmer is forecasted to expand 19-fold by the end of the century to cover more than 25 million km$^2$. While North Pacific primary production is projected to be only 6% lower at the end of the century, the model projects a 24% decline in the proportion of large phytoplankton biomass, implying reduced energy flow to top trophic levels.

**27 April, 9:30 (B1-6167)**

## Effects of climate forcing on the North Pacific Ocean ecosystem simulated using an eddy-permitting marine ecosystem model

Hiroshi **Sumata**[1], Taketo Hashioka[2], Takeshi Okunishi[3], Masahito Shigemitsu[1], Maki N. Aita[2], Naoki Yoshie[4], Naosuke Okada[1], Takashi T. Sakamoto[2], Tatsuo Suzuki[2] and Yasuhiro Yamanaka[1,2]

1 Graduate School of Environmental Earth Science, Hokkaido University, N10W5 Kita-ku, Sapporo, Hokkaido, 060-0810, Japan E-mail: su@ees.hokudai.ac.jp
2 Japan Agency for Marine-Earth Science and Technology, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa, 236-0001, Japan
3 National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa, 236-8648, Japan
4 Center for Marine Environmental Studies, Ehime University, 2-5 Bunkyo-cho, Matsuyama, Ehime, 790-8577, Japan

We developed a marine ecosystem model in the global domain and performed a 46 year hindcast experiment to examine the effects of climate forcing on the spatiotemporal variation of basin-scale biogeochemical cycles and biological production. A marine ecosystem model, NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography), was extended to represent biogeochemical cycles in the global domain: application of optimal uptake kinetics of nutrients by phytoplankton, explicit representation of iron cycles in the water column and its limitation on the growth rate of phytoplankton, representation of two size classes of sinking particles, optimal parameter estimation by gene algorithm, *etc.* The ecosystem model was coupled with an Ocean General Circulation Model, COCO (CCSR Ocean Component Model) Ver. 4.3, by an offline method. The model has horizontal resolution of 0.25125 degree in longitude and 0.1875 degree in latitude with 51 vertical levels, covering the entire domain of the global ocean. The physical part of the model was driven by interannual climate forcing from 1959 to 2004, and reasonably simulated interannual to decadal variabilities of ocean conditions related to biogeochemical cycles. Nutrient supply from river runoff and iron supply from dust deposition and sediment sources is also considered for realistic representation of ecosystem response. The model demonstrated the importance of variations of climate forcing with various spatiotemporal scales on basin-scale biological production. In our presentation, we will focus our attention on the ecosystem behavior in response to interannual to decadal variations of climate forcing in the North Pacific Ocean.

**27 April, 9:45 (B1-6049)**

## The response of eastern Bering Sea zooplankton communities to climate fluctuations: Community structure, biodiversity, and energy flow to higher trophic levels

Jeffrey M. **Napp**[1], George L. Hunt, Jr.[2], Lisa B. Eisner[3], Edward W. Farley[3], Phyllis J. Stabeno[4], Alex Andrews[3] and Atsushi Yamaguchi[5]

1 NOAA/NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115-6349, USA
E-mail: jeff.napp@NOAA.gov
2 School of Aquatic and Fishery Sciences, University of Washington, P.P. Box 355020, Seattle, WA, 98195-5020, USA
3 NOAA/NMFS, Alaska Fisheries Science Center, 17109 Pt. Lena Loop Rd., Juneau, AK, 99801-8344, USA
4 NOAA/OAR, Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA, 98115-6349, USA
5 Graduate School of Fisheries, Hokkaido University, 3-1-1 Minato-cho, Hakodate, 041-8611, Japan

Eastern Bering Sea shelf fisheries are among the world's most productive, and the ecosystem that supports these fisheries has shown rapid and demonstrable changes to climate as predicted for high latitude systems. Zooplankton production is an important variable contributing to production at higher trophic levels. In recent years we have seen large changes in zooplankton community composition and biomass which have had strong, direct affects on planktivorous taxa as diverse as walleye pollock (*Theragra chalcogramma*), seabirds (*Aethia pusilla* and *A. cristatella*), and baleen whales (*Eubalaena japonica*), demonstrating that these changes affect the energy flow and carrying capacity of the region. The biomass time series (T/S *Oshoro-Maru*), as well as community composition data from two of NOAA's ecosystem observation programs (EcoFOCI and BASIS), show increases in the biomass and abundances of key species with the return to cold conditions (*e.g. Calanus, Neocalanus, Thysanoessa raschii*). These large mesozooplankton species are important prey for planktivores. It is uncertain whether decreases in zooplankton biomass during the warm period were also accompanied by increases in biodiversity, as seen in some ecosystems. We report on recent changes in community composition by comparing summer and spring zooplankton community composition data from three years, 2005 (warm), 2006 (cool) and 2007 (cold). In addition, we examine whether our conclusions about climate-mediated changes to the summer zooplankton community and the carrying capacity are robust to the time of sampling (biomass, change in species composition, and the location of the front between the northern and southern regions).

**27 April, 10:00 (B1-6168)**

## Larval fish assemblages in the waters around Taiwan, western North Pacific: A comparison between, during and after the northeasterly monsoon

Hung-Yen **Hsieh**[1], Wen-Tseng Lo[2], Long-Jing Wu[1], Huang-Pin Chien[3], Deng-Cheng Liu[3] and Wei-Cheng Su[3]

1 Coastal and Offshore Resources Research Center, Fisheries Research Institute of the Council of Agriculture, Executive Yuan, Kaohsiung, Taiwan, 80672, ROC. E-mail: hyhsieh@mail.tfrin.gov.tw
2 Department of Marine Biotechnology and Resources, National Sun Yat-sen University, Kaohsiung, Taiwan, 80424, ROC
3 Fisheries Research Institute of the Council of Agriculture, Executive Yuan, Keelung, Taiwan, 20246, ROC

The objective of this study was to investigate the spatio-temporal difference of larval fish assemblages related to the local hydrographic features that occur during (winter) and after (spring) the northeasterly monsoon in the waters around Taiwan. A total of 426 taxa of larval fish belonging to 213 genera and 109 families were recognized during our study period. Larval fish abundances in the two seasons were similar, but the species compositions showed significant difference and the species number of larval fish was more diverse in spring than in winter. MDS analysis revealed two seasonal station groups. Higher abundance and lower species diversity generally were found in the waters west of Taiwan where the China Coastal Current (CCC) prevails, and an opposite trend was observed in the waters east of Taiwan where the Kuroshio Current (KC) dominates. The distribution patterns in abundance and species assemblages were closely linked with the hydrographic conditions, and well-matched with abundance of phyto- and zooplankton. Food availability may be another important factor affecting the distribution of larval fish assemblage in the waters around Taiwan. In addition, the intrusion of the Kuroshio Branch Current (KBC) may bring larvae of some fish species into the Taiwan Strait in spring. The succession of water masses induced by monsoon apparently also affects distribution patterns of larval fish assemblages in the waters around Taiwan.

**27 April, 10:15 (B1-6235)**

## Changes of bottom ichthyocenosis structure on the shelf of west Kamchatka under changing environments in the last two decades

Nadezhda L. **Aseeva** and Alexander L. Figurkin

Far-Eastern Seas Fisheries Resources, Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), 4 Shevchenko Alley, Vladivostok, Primorsky Kray, 690950, Russia. E-mail: aseeva_n@hotmail.com

Tendencies in quantitative structure of the bottom fish community on the shelf of west Kamchatka are considered for the last two decades. The leading groups of this community are flounders (Pleuronectidae), cod and pollock (Gadidae), and sculpins (Cottidae), the combined biomass of which exceeds 90% of the whole community biomass. A long period of warming in the Okhotsk Sea in 1983-1997 with lowered ice cover, relatively small production of dense bottom water, and lowered content of dissolved oxygen in the subsurface layer caused a significant change in the structure of bottom community. Flounders became absolutely dominant: the share of their total biomass in the community increased from about 50% in the 1980s to 64-75% in 1996-1997, and their absolute biomass also increased. In contrast, the shares of gadids and sculpins decreased during 1990s to the minimum in 2001. Resumption of severe winters in 1998-2002 did not lead to restoration of the bottom ichthyocenosis structure: in the early 2000s the share of flounders decreased slightly and the share of sculpins increased, but the abundance of cods and pollock remained low. At the same time, the flounders had a prominent redistribution: their biomass declined in the southern part of the shelf, but increased in its northern part. Recent warming after 2003 caused further declines of the Gadidae, new declines of sculpins, and renewed increases of flounder populations, the biomass of which reached 61% of the bottom community in 2009. Minor populations, such as sea poachers, increased concurrently. Although shifts of environmental factors back to previous conditions led to some recovery in the bottom fish community, there was a certain lag, including a delay in pelagic community recovery. Possible reasons of this delay are discussed.

**27 April, 10:30 (B1-6216)**

## Climate change leads to earlier seasonal occurrence of larval fishes in the southern California Current

Rebecca G. **Asch** and David M. Checkley, Jr.

Scripps Institution of Oceanography, University of California San Diego, 9500 Gilman Dr., La Jolla, CA, 92093-0208, USA
E-mail: rgasch@ucsd.edu

Global warming has prompted an earlier arrival of spring in numerous ecosystems. It is uncertain whether such a change is occurring in the California Current Ecosystem (CCE), because this region is subject to decadal climate oscillations and regional climate models predict seasonal delays in upwelling. We investigated changes in larval phenology of 12 fish species sampled by California Cooperative Oceanic Fisheries Investigations between 1951-2008. Trends in monthly larval abundance were analyzed by decadally averaging data from quarterly surveys conducted in different months. Phenological shifts were quantified by anomalies in the central tendency (CT) of larval abundance. The CT of the ichthyoplankton assemblage advanced by 19.5 days since the 1950s (3.9 days per decade). Species showing phenological advances include *Trachurus symmetricus*, *Merluccius productus*, *Scomber japonicus*, *Diogenichthys atlanticus*, *Symbolophorus californiensis*, and *Triphoturus mexicanus*. Spring-spawning fishes exhibited the fastest rates of phenological change (7.4-9.8 days earlier per decade). In contrast, a few species displayed a delay in CT or an oscillating pattern where an initial advance in phenology was followed by a delay. El Niño did not have a significant effect on the assemblage's CT. While the CT of coastal upwelling and zooplankton volume did not show signs of phenological advance, an inverse relationship between year and SST CT indicated earlier warming of surface waters. A tight correlation was observed between SST CT and the ichthyoplankton assemblage's CT ($r=0.99$, $p<0.001$). The rate of phenological advancement displayed by fishes in the southern CCE is comparable to other regions, such as the North Sea.

**27 April, 11:05 (B1-6220)**

## Ocean climate change and phenology: Effects on trophic synchrony and consequences to fish and seabirds in the northern-central California Current

William J. Sydeman[1], Bryan A. Black[2], Steven J. Bograd[3], Jeff Dorman[4], John C. Field[5], Kyra L. Mills[1], Stephen Ralston[5], T. Zack Powell[4], Jarrod A. Santora[1], Isaac D. Schroeder[1], Sarah Ann Thompson[1] and Franklin B. **Schwing**[3]

1 Farallon Institute for Advanced Ecosystem Research, P.O. Box 750756, Petaluma, CA, 94975, USA. E-mail: wsydeman@comcast.net
2 Oregon State University, Hatfield Marine Science Center, 2030 SE Marine Science Dr., Newport, OR, 97365, USA
3 Pacific Fisheries Environmental Laboratory, 1352 Lighthouse Ave., Pacific Grove, CA, 93950-2097, USA
4 Integrative Biology, UC Berkeley, 3060 Valley Life Sciences Bldg. #3140, Berkeley, CA, 94720-3140, USA
5 NOAA Fisheries, Southwest Fisheries Science Center, 110 Shaffer Rd., Santa Cruz, CA, 95060, USA

The marine climate of the California Current has changed in many ways (*e.g.*, warming, increased stratification), consistent with expectations under global warming. One of the consequences of these physical changes appears to be increasing trophic asynchrony which has, in some years, destabilized predator-prey interactions. It is hypothesized that increased climate variability, as a consequence of climate change, will cause changes in the timing of key seasonal events, such as the spring phytoplankton bloom, dates of diapause for zooplankton, or nesting dates in seabirds. However, it is not well known how these changes will impact predator-prey relationships at higher trophic levels. Several mechanistic hypotheses have been put forth to explain changes in fish production in relation to phenological variability of prey, including Cushing's (1990; *Adv. Mar. Biol.* 26:249–293) 'match-mismatch' hypothesis, yet there have been few tests of these ideas relative to ongoing ocean climate change. We have conducted comprehensive retrospective analyses of the nexus between marine climate, phenology, and trophic synchrony in the northern-central California Current, focusing on krill and juvenile rockfish as 'prey', and seabirds, salmon, and adult rockfish as 'predators' over a recent period of unprecedented climate variability. We found key climatic determinants of predator timing of breeding and reproductive success (seabirds), and growth (rockfish) which were related primarily to winter atmospheric-oceanographic coupling. We also found spatial, and to a lesser extent temporal, 'mismatches' in krill-krill predator interactions, which is apparently related to changes in surface winds, ocean circulation, and plankton transport.

**27 April, 11:20 (B1-6042)**

## Global distribution of phytoplankton functional types estimated from satellite ocean colour

Takafumi **Hirata**[1], Robert Brewin[2] and Nick Hardman-Mountford[3]

1 Hokkaido University, School of Environmental Earth Science, N10W5 Kita-Ku, Sapporo, Japan. E-mail: takafumih@niklis.com
2 University of Plymouth, School of Marine Science and Engineering, Drake Circus, Plymouth PL4 8AA, UK
3 Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth, PL1 3BY, UK

An ocean colour algorithm to estimate several phytoplankton functional types (PFTs) is developed to enable quantitative analysis of global spatial and temporal variability. Each PFT was represented in terms of percentage of total chlorophyll *a* (%TChla). Mean uncertainty of the global pigment relationships is estimated to be 2-9%, depending on PFTs under consideration. Spatially, large populations of microplankton such as diatoms are found in mid-high latitudes. Areas dominated by diatoms (%TChla > 50%) are rather patchy in the global oceans, and found to vary seasonally. Nanoplankton are widely spread and make up a large proportion of the total phytoplankton community (30-50% on average, depending on ocean basins), though their population is relatively small in the subtropical gyres. Large proportions (%TChla > 50%) of pico-plankton such as *Prochlorococcus* sp. are found in the subtropical gyres, and pico-eukaryote species are relatively abundant in the South Pacific. Long term trends over 1998-2007 for each PFT were also determined. Statistically significant trends were found in most ocean basins. Statistically significant increasing trends were found for picoplankton (prokaryotes and pico-eukaryotes), while statistically significant decreasing trends were found for diatoms and nanoplankton.

**27 April, 11:35 (B1-6363) (*Moved to 16:45*)**

## Comparison of the ecosystem response to climate change in the mid-latitude North Pacific and California Current ecosystems

Ryan R. **Rykaczewski**[1] and John P. Dunne[2]

[1] University Corporation for Atmospheric Research, Geophysical Fluid Dynamics Laboratory, 201 Forrestal Rd., Princeton, NJ, 08540-6649, USA. E-mail: ryan.rykaczewski@noaa.gov
[2] NOAA Geophysical Fluid Dynamics Laboratory, 201 Forrestal Rd., Princeton, NJ, 08540-6649, USA

Historical observations of mid-latitude ocean ecosystems display strong, negative correlations between temperature and nutrient concentration (and productivity) in the mixed layer over interannual to decadal time scales. We examine changes in the relationship between temperature and nutrients in the California Current and the oligotrophic North Pacific ecosystems under a scenario of increased greenhouse-gas concentrations using an atmosphere-ocean general circulation model coupled to an ocean biogeochemical model (GFDL's ESM 2.1). We find that nitrate concentration and productivity decrease in the euphotic zone of the oligotrophic North Pacific with increases in temperature and stratification, consistent with the relationships observed over shorter time scales. However, the response in the California Current is opposite: nitrate concentration and productivity increase with increases in temperature and stratification over the centennial time scale. This result is contrary to the relationship observed over shorter time scales in mid-latitude ocean ecosystems but is consistent with observations of nutrient concentration and temperature over multidecadal scales in the California Current. Although we find that the total equatorward transport in the surface layers of the California Current increases, the increase in nitrate concentration in the euphotic zone is due primarily to increased flux from the poleward undercurrent rather than flux from the north or west. This work emphasizes the need for a greater understanding of nutrient dynamics in the region and suggests that empirical relationships among temperature, nutrient supply, and biological production based on historical observations at interannual to decadal time scales may be inappropriate for predicting ecosystem responses under climate-change scenarios.

**27 April, 11:50 (B1-6279)**

## A preliminary study of the effects of a wave exposure gradient on the species richness of marine macrophytes along the eastern rim of the East China Sea

Gregory N. **Nishihara**[1] and Ryuta Terada[2]

[1] Institute for East China Sea Research, Nagasaki University, 1551-7 Taira-machi, Nagasaki City, Nagasaki, 851-2213, Japan E-mail: greg@nagasaki-u.ac.jp
[2] Division of Fisheries Biology and Oceanography, Kagoshima University, 4-50-20 Shimoarata, Kagoshima City, Kagoshima, 890-0056, Japan

Changes in the global climate are expected not only to increase water temperature and decrease pH, but also to affect tidal range and wave heights. Whether or not there will be increases or decreases in sea surface winds and hence wave heights is the subject of ongoing research. However, there is no doubt that these changes will affect coastal ecosystems throughout the world. Macrophytes, which provide habitat for a variety of benthic and pelagic organisms, are expected to be greatly influenced by changes in coastal wave climate, since they occupy coastal areas that are under the heavy influence of waves. Given that waves are one of the primary factors influencing physical and biological processes in these environments, we believe that understanding the relationships between macrophytes and waves will help prepare us for the changes in climate that are predicted to occur. We will address the effects of a wave exposure gradient on species richness over a 600 km north-south gradient along the eastern rim of the East China Sea. Over 400 species of macrophytes across more than 200 survey sites were sorted based on morphological characteristics (*i.e.*, functional form) to elucidate how waves may affect different groups of species. We provide a testable hypothesis and propose that macrophyte richness decreases with increasing wave exposure throughout the domain and is strongly influenced by functional form.

**27 April, 12:05 (B1-6253)**

## Climate-driven shifts in marine fish communities indicated by commercial catch statistics from Korean coastal waters

Sukgeun **Jung**, Young Shil Kang, Young-Sang Suh, Sukyung Kang and Yeong Gong

National Fisheries Research and Development Institute, 408-1 Sirang-ri, Gijang-eup, Gijang-gun, Busan, 619-902, R Korea
E-mail: Sukgeun.jung@gmail.com

To evaluate and project effects of climate-driven oceanographic changes on Korean fisheries, we summarized changes in oceanographic conditions (1968-2007), volume transports of the Tsushima warm current (TWC) and cold waters, taxonomic changes in fishery catches (1968-2008), and zooplankton biomass and taxonomic compositions in Korean coastal waters (1978-2006). Water temperatures and zooplankton biomass density, averaged for the entire Korean sea waters, have increased significantly. Although the combined annual fishery catch has been relatively stable since 1980's, annual catch of individual fish species has fluctuated more greatly. Catch from shallow, inshore areas has decreased, but catch from deep, offshore areas has increased. We could define four regimes based on characteristic fish species identified by correspondence analysis: 1) saury (1968-1976), 2) pollock (1977-1982), 3) sardine (1983-1990) and common squid (1991-2008). Because these four species have been major fisheries species in the Korea Strait and Japan/East Sea, which are under the influence of the TWC, we are currently analyzing seasonal and annual variations in volume transports of the TWC and bottom cold waters through the Korea Strait. An additional shift in species compositions of both fisheries catch and zooplankton in Korean waters was evident for 1982-1983, which was probably related with the El Niño event. The comparison between the reported periods of basin-wide climatic and ecosystem changes and our proposed shifts in Korean marine capture fishery suggests that climate-driven oceanic changes has been a major cause of changes in fish communities in Korean sea waters.

**27 April, 12:20 (B1-6329)**

## Interdisciplinary monitoring for the Kuroshio warm current ecosystem in relation to climate change

Hiroya **Sugisaki**[1], Kiyotaka Hidaka[1], Tadafumi Ichikawa[1], Yutaka Hiroe[1], Yuichi Hirota[2], Kenji Morinaga[1], Manabu Shimizu[1], Takahisa Tokunaga[1], Mikiko Kuriyama[1], Tomowo Watanabe[1] and Kaoru Nakata[1]

[1] National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa, 236-8648, Japan. E-mail: sugisaki@affrc.go.jp
[2] Kochi Station of National Research Institute of Fisheries Science, Fisheries Research Agency, 6-1-21 Sanbashi-dori, Kochi, 780-8010, Japan

The Kuroshio is the western boundary warm current in the North Pacific and it is known as a main spawning field of various commercially-important pelagic fishes (*e.g.* Japanese sardine, Pacific saury, chub mackerel), although nutrient concentration and biological production has been low compared to Oyashio cold current area. Large-scale and long-term variations of stock size of these pelagic fish species related to climate change have been observed. We have been conducting interdisciplinary, physical-chemical-biological monitoring research in the Kuroshio ecosystem since the 1980s because the survival rate and success of recruitment of early life stages of commercially important pelagic fish species are determined by a combination of multiple factors. These include variations in transportation route, speed of the Kuroshio Current, and food condition.

The scale and timing of the spring bloom in the Kuroshio has varied interannually, based on chlorophyll *a* concentration. The interannual variation of primary production seems to be related to the variation of water temperature and meander pattern of the Kuroshio Current. The interannual variations of the scale and timing of low trohic level production seem to affect the fluctuation of nutritional condition for survival of larval pelagic fishes. This retrospective Kuroshio ecosystem monitoring study has provided key insights into the mechanisms driving the observed large scale variations of stock sizes of commercially-important pelagic fish in relation to climate change and physical characteristics of the Kuroshio Current (*e.g.* meander pattern).

**27 April, 12:35 (B1-6101)**

## Understanding and forecasting of fish species alternation in the Kuroshio-Oyashio ecosystem: The SUPRFISH programme

Hiroaki **Saito**[1], Shin-ichi Ito[1], Atsushi Kawabata[2], Mitsutaku Makino[2], Masami Nonaka[3], Takeshi Okunishi[2], Kazutaka Takahashi[1] and Ichiro Yasuda[4]

1 Tohoku National Fisheries Research Institute, Fisheries Research Agency, 3-27-5 Shinhama-cho, Shiogama, Miyagi, 985-0001, Japan
E-mail: hsaito@affrc.go.jp
2 National Research Institute of Fisheries Science, FRA, 2-12-4 Fukuura, Kanazawa, Yokohama, 236-8648, Japan
3 JAMSTEC, 3173-25 Showa-machi, Kanazawa, Yokohama, 236-0001, Japan
4 Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo, 164-8639, Japan

Fish species alternation between sardine and anchovy (FSA-SA) is the most drastic phenomenon of ecosystem regime shift responding to climate change. Most FSA-SA are observed in upwelling zones in the eastern part of oceans. The exception is the Kuroshio-Oyashio ecosystem off Japan in the western boundary current system of the North Pacific. In spite of the different physical oceanographic characteristics, the FSA-SA in the Kuroshio-Oyashio often synchronizes with other FSA-SA regions in upwelling zones. The mechanism inducing the FSA-SA in upwelling zones and the western boundary current system has been a premier scientific issue of ocean sciences. In order to understand the mechanism of FSA-SA and to forecast the future FSA-SA in the Kuroshio-Oyashio ecosystem, we started the SUPRFISH (Studies on Prediction and Application of Fish Species Alternation) programme. The SUPRFISH has 5 research themes: 1. Physical oceanographic variations inducing marine ecosystem regime shifts; 2. Mechanisms and processes of change in lower food-web structure; 3. Physiological and ecological factors of pelagic fishes related to the FSA; 4. Development of a mathematical model representing FSA; and 5. Application of FSA results and theory in fisheries management. In the presentation, we will show the science plan of SUPRFISH, results obtained thus far, and the strategy to develop the FSA forecasting technique.

**27 April, 14:30 (B1-6044), Invited**

## Interesting times

Elizabeth A. **Fulton**

CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania, 7001, Australia. E-mail: beth.fulton@csiro.au

Feedback and change are fundamental features of ecosystems, something global change has highlighted. Changes in the physical environment, will see shifts in species ranges, community compositions and ultimately the form and function of ecosystem and the human societies that exploit them. What these shifts will be depends on which of the competing (and potentially counteracting) mechanisms dominates through space and time. This means that changes are unlikely to be simple or linear, there will be winners, losers and surprises. It also means that management will be complex and non-stationary, presenting management, scientific and statistical challenges.

**27 April, 14:55 (B1-6164)**

## Decline in mackerel fishery along west coast of India and its relation to the diminishing density of an abundant upwelling copepod: A multi-decadal study

Rosamma **Stephen**

Ajantha, Elamkulam Rd., Kochi-682017, Kerala, India. E-mail: rosamma.stephen@gmail.com
Scientist (Retired), National Institute of Oceanography, Regional Centre, Kochi-682018, Kerala, India

The alarming decrease in the mackerel fishery along the west coast of India in recent years is attributed by fishery scientists to various factors, but primarily SST increases and shifting of the population to deeper waters. So far, no attempt has been made to analyze the relationship between copepods and mackerels. In this paper, copepod data collected from India's EEZ during the past four decades are compiled, and *Temora turbinata* is used as a key indicator species relating to upwelling and mackerel fisherydata published by India's Central Marine Fishery Research Institution. A synthesis of *T. turbinata* data collected during the last four decades indicated a sweeping decline in the population of this species during the summer monsoon. The herbivorous species *T. turbinata* occur in swarms over the entire shelf following pulses of diatom blooms in upwelling areas. Data

utilized for this study spanned the period from the International Indian Ocean Expedition (IIOE, 1960-65) until the Marine Research on Living Resources project (MRLR, 1998-2005). The density of *T. turbinata* individuals in the mixed layer decreased from 5000-30000/100m$^3$ during 1980's to 200-1600/100m$^3$ during 1998-2005. Swarms of *T. turbinata* during the summer monsoon of 1970-75 were associated with low temperature between 19.9 and 23.8°C in the mixed layer. Diapause, which allows *Calanoides carinatus* to cope with environmental fluctuations, is not reported for *T. turbinata*. Several lines of evidence suggest that the mackerel fishery is directly related to the abundance and species composition of copepods.

**27 April, 15:10 (B1-6336)**

## Effect of climate change on fish and fisheries of Marathwada region of Maharashtra state (India)

Sunil D. **Ahirrao**

Fresh Water Aquaculture Division, Department of Fisheries, Shri Shivaji College, Parbhani, (M.S.), India
E-mail: Ahirrao.sunil@gmail.com

India is an under-developed country and its national economy is based on agriculture. Among of that agriculture fish and fisheries are the important component of Indian economy and health of common peoples. The state of Maharashtra serves a prominent role in the Indian economy, and much of the foreign exchange flowing into Maharashtra results from exports of fish and fish products. Marathwada region consists of 8 districts: Aurangabad, Jalna, Parbhani, Nanded, Hingoli, Latur Osmanabad and Beed. These make up the study area in which sampling was conducted and observations made.

The present findings are compared with my earlier findings from the year 2000. The study deals with the varies parameters to compare with earlier findings such as water level, water temp, atmospheric temp, precipitation, humidity, fish biodiversity, species distribution, fish production in kg/ha/year, district-wise species distributions, accounting of rare and threatened and migratory species, *etc.* Overall, the combined effects of decreasing fish biodiversity, changes in water level, and decreasing precipitation have led to degraded fisheries ecosystems. This may be due to increased temperatures, pollution load, and shifting seasonal cycles, and all of this may be attributed to climate change.

**27 April, 15:25 (B1-6056)**

## Long-term climate-driven changes in UK marine fish communities

Stephen D. **Simpson**[1], Mark P. Johnson[2], David W. Sims[3], Pieter-Jan Schön[4], Julia L. Blanchard[5], Simon Jennings[5] and Martin J. Genner[1]

1 School of Biological Sciences, University of Bristol, Woodland Rd., Bristol, BS8 1UG, UK. E-mail: Stephen.Simpson@bristol.ac.uk
2 The Martin Ryan Marine Science Institute, National University of Ireland Galway, University Rd., Galway, Ireland
3 Marine Biological Association of the UK, the Laboratory, Citadel Hill, Plymouth PL1 2PB, UK
4 Agri-Food and Biosciences Institute, Newforge Lane, Belfast, Northern Ireland, BT9 5PX, UK
5 Centre for Environment Fisheries and Aquaculture Science, Cefas Lowestoft Laboratory, Pakefield Rd., Lowestoft, Suffolk, NR33 0HT, UK

Evidence is mounting for long-term effects of climate change on marine fish assemblages. Until now, much of this work has been conducted over short or intermittent time periods, or small geographical areas. Here we present the findings of a macrospatial study of the entire UK marine fish assemblage measured annually for a 30-year period by commercially-independent trawls. We find clear support for the previously reported North Sea shift in community assemblage in the late-80s to early-90s, but also evidence of community change in NW Scotland, the Channel, and the Celtic and Irish Seas. Using newly developed analytical approaches we have explored these patterns at a fine spatio-temporal resolution, and for the first time present the relationships between measured community change and key environmental drivers. Through a series of hypothesis-driven investigations of these patterns, we have explored the species-level responses with respect to temperature and depth preferences, and life-history characteristics and phylogeographic history. We use these findings to draw out fundamental properties of ecosystem function, community response, and life-history vulnerability. Finally, by extrapolating current trends we present our 'best guess' predictions for the future of marine fish assemblages and fisheries.

**27 April, 15:40 (B1-6078)**

## Global warming changes the species richness of marine fish in the eastern North Atlantic Ocean

Remment **ter Hofstede**, Jan Geert Hiddink and Adriaan D. Rijnsdorp

IMARES (Institute for Marine Resources and Ecosystem Studies) P.O. Box 68, 1970 AB IJmuiden, The Netherlands
E-mail: remment.terhofstede@wur.nl

Global warming causes changes in local communities due to species extinctions and latitudinal ranges shifts. We show that the species richness of fish in three regional seas in the eastern North Atlantic Ocean changes over time (1997-2008) and we relate this to higher water temperatures and the biogeographic affinity of the species. In two of the areas, the species richness increased due to increases in the number of warm-loving Lusitanian species. In the third area, species richness decreased since the number of cold-favouring Boreal species decreased. Analyses of trends in fishing effort indicate that the observed changes in species richness are not fisheries-induced, thereby making global warming the most plausible factor to have caused the changes in species richness of marine fish.

**27 April, 15:55 (B1-6305)**

## Changes in the environmental factors controlling the global biogeography of tuna and billfish communities

Gabriel **Reygondeau**, Olivier Maury, Hervé Demarcq and Philippe Cury

IRD (Institut de Recherche pour le Développement), UMR EME 212, CRH (Centre de Recherches Halieutiques Méditerranéennes et Tropicales), Av. Jean Monnet, B.P. 171, 34203 Sète cedex, France. E-mail: gabriel.reygondeau@ird.fr

Biogeography attempts to investigate the link between the spatial distribution of species and the environment. In this perspective, the global marine biogeography proposed by Longhurst based on physical, chemical and biogeochemical (chlorophyll concentrations derived from satellite images) variables constitutes the most widely accepted reference. However, few attempts have tried to assess its validity for upper trophic levels (zooplankton or fish). In the present study, we investigate the biogeography of tunas and billfishes. First, we implement a new numerical procedure based on hierarchical clustering and a non-parametric probabilistic model to identify regions where top predator communities are homogeneous. This procedure is applied to a database gathering fifty years of spatialized commercial long line catches of fifteen different species of tuna and billfish at the global scale. Second, for every identified region, the species composition and the associated environment (using twelve environmental factors) is characterized. The obtained top predator biogeography is compared to Longhurst partitions. Third, the trends of every environmental factor structuring the tuna and billfish communities are analysed during the last decade using a wavelet analysis. Our results suggest that the different tuna and billfish species occupy different niches at the global scale and form specific and well-defined communities. We show that our top predator biogeography matches well with Longhurst biomes and provinces. This has important implications for understanding the spatial distribution of biodiversity and regional ecosystem structure. Furthermore, significant changes in the environmental structure of some specific regions are detected and could be amplified by climate change, with potentially important consequences on the spatial distribution and species composition of the identified top predator communities.

**27 April, 16:30 (B1-6366)**

## Modeling global patterns in the transfer of energy between primary producers and mesozooplankton in a global circulation model

Charles A. **Stock** and John P. Dunne

NOAA Geophysical Fluid Dynamics Laboratory, Princeton University Forrestal Campus, 201 Forrestal Rd., Princeton, NJ, 08540-6649, USA. E-mail: charles.stock@noaa.gov

Climate model simulations in the CMIP3 multi-model database were generally focused on the physical climate system (sea ice, atmosphere, ocean and land surface). Where marine ecosystem models were included, they emphasized global scale cycling of carbon and nutrients and representations of the food web were highly simplified. As a result, predictions of the response of living marine resources (LMRs) to climate change have relied heavily upon empirical relationships with projected physical variables or primary production. To address this, the food web dynamics within the Geophysical Fluid Dynamics Laboratory's Earth System Model have been augmented to include multiple zooplankton groups with basic bioenergetics. First, a simplified marine ecosystem model and a synthesis of *in-situ*, laboratory, and satellite data were used to reveal and explain global-scale patterns in energy transfer from primary producers to mesozooplankton. It was found that, on average, only 1-4% of primary production is translated to mesozooplankton production in relatively low productivity ecosystems (*e.g.*, subtropical gyres) compared with 10-20% in highly productive areas (*e.g.*, coastal upwelling systems). An important implication of this result is that climate-driven fractional changes in primary production may be magnified into larger fractional changes in mesozooplankton production and production of higher trophic levels. The food web dynamics from this idealized model were then integrated with GFDL's existing biogeochemical model. Global simulations forced with historical atmospheric forcing from the past 60 years will be presented with analysis of both the mean state was well as interannual to decadal scale variability in trophic transfer.

**27 April, 16:45 (B1-6108) (*Changed to Poster*)**

## Climate Forcing and Marine Ecosystems of the North Pacific

Jacquelynne R. King[1], Vera N. Agostini[2], Gordon McFarlane[1], Christopher Harvey[3], Michael **Foreman**[4], James E. Overland[5] and Kerim Aydin[6]

1 Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
E-mail: Jackie.King@dfo-mpo.gc.ca
2 The Nature Conservancy, Global Marine Initiative, 1917 First Ave., Seattle, WA, 98101, USA
3 Northwest Fisheries Science Center, National Marine Fisheries Service, 2725 Montlake Blvd. E., Seattle, WA, 98112, USA
4 Fisheries and Oceans Canada, Institute of Ocean Sciences, P.O. Box 6000, Sidney, BC, V8L 4B2, Canada
5 Pacific Marine Environmental Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, 7600 Sand Point Way NE, Seattle, WA, 98115-6349, USA
6 Alaska Fisheries Science Center, National Marine Fisheries Service, 7600 Sand Point Way NE, Seattle , WA, 98115-6349, USA

The Climate Forcing and Marine Ecosystems (CFAME) Task Team of PICES was formed to address climate forcing impacts on ecosystem structure and productivity of key species. The Task Team was comprised of climatologists, physical and biological oceanographers and fisheries scientists thus drawing from a multi-disciplinary team for the prediction of North Pacific marine ecosystems response to basin-wide climate forcing events. Three major ecosystems of the North Pacific were selected for this approach: California Current System, the Sea of Okhotsk and the East China/Yellow Sea. For each ecosystem the Task Team described the physical processes that define each ecosystem, built an overview of species across trophic levels that represented all life history strategies and described how the population dynamics of these species have changed overtime. In this talk we will focus on the conceptual model developed for the California Current System (CCS) describing the potential mechanisms linking climate forcing, oceanography and species' responses. Our resultant scenarios draw on ecosystem histories to provide a synopsis of expected change given global climate change. The multi-disciplinary team faced challenges and limitations in their attempt to draw connections between the outputs from GCMs, the physical processes and the subsequent impacts on species via the identified mechanisms. To some degree there was a mismatch of variables that fisheries scientists identified as important in determining species' response to climate and physical forcing, and the variables that current GCMs and ROMs are currently able to resolve at the regional level. These gaps will be important for researchers to consider as they begin to develop higher resolution climate and regional oceanographic models for forecasting changes in species' productivity.

**27 April, 17:00 (B1-6061)**

## Modeling the central North Pacific ecosystem response to predicted climate variations and fishery management scenarios

Evan A. **Howell**[1], John P. Dunne[2] and Jeffrey J. Polovina[1]

[1] NOAA Fisheries Pacific Islands Fisheries Science Center, Honolulu, HI, 96822, USA. E-mail: Evan.Howell@noaa.gov
[2] NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, 08540, USA

To understand how climate and habitat variability may affect ecosystems such as the central North Pacific Ocean (CNP), it is important to be able to quantify trophic interactions and energy flows of the organisms within the system. In this study, the Ecopath with Ecosim (EwE) model framework was used to understand the dynamic relationships between the species within this ecosystem under different projected scenarios. An existing EwE model of the CNP was adapted to represent the region used by the Hawaii-based pelagic longline fishery and expanded in scope to include two phytoplankton and zooplankton groups as well mid-trophic level species of growing recent importance to this fishery. Ecopath was used to balance the updated CNP model and Ecosim was then used to predict CNP ecosystem responses from possible changes in both the fishery and predicted climate variability. Ecosim projections to the year 2100 were run using three scenarios. Scenario one was comprised of top-down forcing represented by changes in fishing pressure on species of interest to fishers and management. Scenario two was comprised of bottom-up forcing represented by changes in phytoplankton biomass taken from the NOAA Geophysical Fluid Dynamics Laboratory's Earth System Model (ESM2.1) that included a biogeochemical and ocean phytoplankton model run under the A2 greenhouse gases forcing scenario. Scenario three was a combination of both. The results from these scenarios show dynamic changes in this ecosystem driven by both predicted climate variability and possible fisheries management measures. An increased understanding of the food web interactions and expected shifts due to different forcing mechanisms in this system will increase our ability to adapt fishery management policies to better maintain sustainable fisheries.

**27 April, 17:15 (B1-6276)**

## Projecting future change in pelagic nekton communities along the west coast of North America

William L. Cheung[1], Thomas A. **Okey**[2,3] and Richard D. Brodeur[4]

[1] School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK. E-mail: William.cheung@uea.ac.uk
[2] West Coast Vancouver Island Aquatic Management Board, #3 4310 10th Ave., Port Alberni, BC, V9Y 4X4, Canada
[3] University of Victoria School of Environmental Studies, Victoria, BC, V8P 5C2, Canada
[4] Northwest Fisheries Science Center, NOAA Fisheries, Hatfield Marine Science Center, 2030 Marine Science Dr., Newport, OR, 97365, USA

Marine ecosystems are being affected by changes in ocean conditions resulting from the effect of greenhouse gas emissions on the global atmosphere. Shifting spatial distributions of species is a major observed and predicted impact of these oceanographic changes, and such shifts may modify community structure considerably in particular locations and regions. We used a dynamic bioclimatic envelope model to project shifting ranges of pelagic marine fish and invertebrates along the west coast of North America, from the coast of California to Alaska. We combined published data, expert knowledge, and survey data to predict current species ranges of 30 pelagic nekton species. Species include sub-tropical and temperate species with different life history patterns. Using projected ocean condition changes from NOAA's GFDL coupled model, we simulate changes in the spatial distribution of each species. Our study shows that the west coast of North America may undergo considerable changes in the structure of its pelagic marine communities by 2055 under a 'business-as-usual' (SRES A1B) climate change scenario. Distributions of the studied species are projected to shift poleward at an average rate of 40 km decade$^{-1}$, resulting in high rates of range expansion in the Gulf of Alaska and northern Bering Sea. Rate of range retraction is highest in southern Bering Sea, and some coastal areas of British Columbia and Oregon. Such changes in species assemblages may have large ecological and socio-economic implications through unexpected trophic effects and shifts in fishing grounds. The results provide alternative hypotheses for future studies to test.

**27 April, 17:30 (B1-6081)**

## Ecology of small neritic fishes in the western Gulf of Alaska: Top-down mechanisms can moderate bottom-up forcing

Matthew T. **Wilson**[1], Christina M. Jump[1] and Andre Buchheister[2]

[1] Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 7600 Sand Point Way NE, Seattle, WA, 98115, USA. E-mail: matt.wilson@noaa.gov
[2] Virginia Institute of Marine Science, P.O. Box 1346, Gloucester Point, VA, 23062-1346, USA

The Gulf of Alaska (GOA) coastal ocean is characterized by strong climate-forced circulation and high biological productivity. Habitat heterogeneity is hypothesized to affect ecosystem productivity. Small neritic fishes (walleye pollock, capelin, eulachon) are prominent trophic intermediaries in ecosystem productivity. Meso-scale geographic associations among the physical environment, zooplankton and these fishes were examined during September 2000, 2001, and 2003 within 41,000 km$^2$ of the continental shelf from near shore to the slope. The study area was chosen due to its location within a major walleye pollock nursery and due to well-known circulation features. The 48-site sampling grid was divided into 5 meso-scale areas based on water temperature, salinity, and model-based net current velocity. Few fish were collected over the slope. Over the shelf, age-1+ walleye pollock and eulachon populations were densest in proximity to sea valleys where net current velocities were high, and where krill, the major prey species, were most abundant. Inter-annually, per capita consumption of krill by fish was highest in 2001 when net current velocities and krill abundance were high. The greatest proportion of the krill standing stock was consumed in 2001. Thus, aggregation of fish and krill in the coastal GOA was associated with the flow field; increased flow in 2001 enhanced krill abundance causing fish to consume a greater proportion of the standing stock (*i.e.* compensatory response). These fishes are therefore expected to benefit from any climate-related intensification of coastal flow due to increased abundance of krill, which are an energy-rich prey.

**27 April, 17:45 (B1-6130)**

## Ocean acidification threatens the replenishment of reef fish populations

Philip L. **Munday**[1], Danielle L. Dixson[1], Mark I. McCormick[1] and Mark Meekan[2]

[1] ARC Centre of Excellence for Coral Reef Studies, and School of Marine and Tropical Biology, James Cook University, Townsville, QLD, 4811 Australia. E-mail: Philip.Munday@jcu.edu.au
[2] Australian Institute of Marine Science, Perth, WA, Australia

Atmospheric carbon dioxide ($CO_2$) concentrations are increasing at an unprecedented rate and could exceed 1000ppm by 2100 unless measures are taken to curb greenhouse gas emissions. The corresponding increase in dissolved $CO_2$ at the sea surface is expected to have serious consequences for marine species, although the $CO_2$ concentrations at which impacts will manifest and the capacity for species' adaptation to ocean acidification remain poorly understood. We used a series of laboratory and field experiments to test the effects of elevated $CO_2$ on the sensory performance of larval reef fishes. Naïve settlement-stage larvae reared in control water exhibited an innate avoidance of the odor from reef-based predators. Behavioral responses of fish larvae to the chemical cues of predators was unaffected by 550ppm $CO_2$. However, at 750ppm $CO_2$ some larvae in each clutch exhibited a dramatic switch from complete avoidance to strong attraction to the predator cue. Other larvae in each clutch remained unaffected by 750ppm $CO_2$. At 1030ppm $CO_2$ all larvae were strongly attracted to the predator cue and there was no variation in response among individuals. These results suggest that adaptation of behavioral responses might be possible at 750ppm $CO_2$ but atmospheric $CO_2$ need to remain below this level to avoid serious impacts on marine biodiversity.

**27 April, 18:00 (B1-6095)**

## Extinction vulnerability of coral reef fishes in response to climate change and fisheries exploitation

Nicholas **Graham**[1], Pascale Chabanet[2], Richard Evans[3], Simon Jennings[4,5], Yves Letourneur[6], M. Aaron MacNeil[7], Tim McClanahan[8], Marcus Öhman[9], Nicholas Polunin[10] and Charles Sheppard[11]

1 ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland, Australia
E-mail: nick.graham@jcu.edu.au
2 Laboratoire d'Ecologie Marine (ECOMAR), Université de La Réunion, Saint-Denis, La Réunion, France
3 Department of Fisheries, 39 Northside Dr. Hillarys, North Beach 6920, Western Australia
4 Centre for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, Lowestoft, UK
5 School of Environmental Sciences, University of East Anglia, Norwich, UK
6 Institut de Recherche pour le Développement, BPA5 Nouméa, New Caledonia
7 Australian Institute of Marine Science, Townsville, Australia
8 Wildlife Conservation Society, Marine Programs, Bronx, New York, USA
9 Department of Zoology, Stockholm University, Stockholm, Sweden
10 School of Marine Science and Technology, Newcastle University, Newcastle-upon-Tyne, UK
11 University of Warwick, Department of Biological Sciences, Coventry, UK

With the advent of the world's sixth mass extinction episode, predictive assessments of species extinction risk and methods to identify how multiple stressors drive non-random species loss, are urgently required. Such assessments are imperative to developing management actions that avoid the loss of key species or functional groups that sustain ecosystem functions and services. A predictive framework to evaluate the extinction risk of coral reef fishes to climate change disturbance was developed and linked with an existing framework for evaluating risk from fisheries exploitation. Obligate corallivores, facultative corallivores and micro-invertebrate feeding functional groups are most vulnerable to climate change disturbances, with local rather than global extinctions more likely for most species. The species most vulnerable to climate variation and change are least vulnerable to fishing and vice-versa, with the consequence that the entire fish community will be impacted on the many reefs where both stressors occur. The groups of fishes involved in key ecosystem functions, including the recovery of reef habitat following disturbance events, are more at risk from fishing impacts. Remarkably, this is an encouraging result, since local and regional commitment to fisheries management action can help to reduce the impacts of climate change on reef ecosystems pending any global progress towards limiting greenhouse gas emissions.

**27 April, 18:15 (B1-6328)**

## Comparison of benthic community structure in natural habitats of abalone *Haliotis discus hannai* affected by different current systems

Nam-Il **Won**[1], Tomohiko Kawamura[1], Hideki Takami[2], Hiroshi Hoshikawa[3] and Yoshiro Watanabe[1]

1 Ocean Research Institute, The University of Tokyo, Nakano, Tokyo, 164-8639, Japan. E-mail: niwon@ori.u-tokyo.ac.jp
2 Tohoku National Fisheries Research Institute, Shiogama, Miyagi, 985-0001, Japan
3 Hokkaido Central Fisheries Experimental Station, Yoichi, Hokkaido, 046-8555, Japan

Climate regime shifts have been suggested to influence fisheries production in various ways. Increasing concerns about the effects of ecosystem level impacts of climate regime shifts on fisheries has given attention to benthic community studies, compared with a long history of focus on pelagic ecosystems. The long time fluctuation of northern abalone (*Haliotis discus hannai*) catch in Japan has been suggested to be closely correlated with the Aleutian Low. The low overwinter mortality of young-of-the-year (YOY) abalone in the warm regime since the mid-1990s has increased the recruitment success of this overfished (collapsed) abalone species. To understand possible impacts of climate regime shifts on benthic community structure in abalone habitats, species composition and trophic structure in habitats *H. discus hannai* were investigated at Iwanai (Hokkaido prefecture) and Tomarihama (Miyagi prefecture) coasts, which are affected by Tsushima Warm Current (TWC) and Kuroshio-Oyashio Current (KOC), respectively. Species replacement was indicated in Tomarihama when compared with community data 20 years ago. The newly occurred *Homalopoma sangarense* appeared to be less competitive with early life stages of abalone for food. In contrast, the previously abundant congener *H. amussitatum* appeared to compete for food with juvenile abalone. This study suggests that climate regime shifts could influence the production of abalone through shifts in trophic relations in the benthic community.

# B1 Posters

### B1-6025

## Thermal refugia in the 21st century

Skip **McKinnell**[1] and Enrique N. Curchitser[2]

[1] PICES Secretariat, P.O. Box 6000, Sidney, BC, V8L 4B2, Canada. E-mail: mckinnell@pices.int
[2] Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ, 08901, USA

It is anticipated that by 2050 the global warming trend in the surface waters of the North Pacific Ocean will have emerged from the background natural variability. Surface ocean temperatures are expected to be routinely warmer than anything observed in human history. Many marine animals are known to have temperature preferences that place limits on their contemporary distributions. While eurythermal animals can tolerate a wide range of temperatures, stenothermal animals must adapt, migrate, or die. Subarctic fauna will be particularly vulnerable because of their connection to a cooler ocean. The ocean depths are a reservoir of cold water but it may not be available to surface-dwelling animals except at times and places where turbulent mixing by winds and tides bring this water to the surface. The upwelling ecosystem of the California Current is a contemporary example of physical processes providing refugia and migration corridors that allow Subarctic animals to survive at lower latitudes. This study uses an high resolution numerical model of the Northeast Pacific (including tides) to compare the thermal landscape of a contemporary summer ocean with what might be expected in a typical summer in the year 2050. We seek to understand where winds and tides in the Northeast Pacific will provide thermal refugia for Subarctic animals and to understand the quantity and location of habitat provided by this mechanism. Because it has been relatively well studied, Pacific salmon habitat will be used as a case study.

### B1-6046

## Potential effects of climate change on the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* off Newport, OR, USA

C. Tracy **Shaw**[1], Leah R. Feinberg[1] and William T. Peterson[2]

[1] Cooperative Institute for Marine Resources Studies, Oregon State University, 2030 SE Marine Science Dr., Newport, OR, 97365, USA
E-mail: tracy.shaw@oregonstate.edu
[2] Northwest Fisheries Science Center, NOAA Fisheries, 2030 SE Marine Science Dr., Newport, OR, 97365, USA

Climate change scenarios suggest that global warming will lead to stronger coastal upwelling and changes in the magnitude and duration of natural climate cycles such as the PDO. Our ongoing biweekly zooplankton sampling program (1996-present) encompasses variations in timing and intensity of upwelling and cool and warm phases of the PDO which allows us to investigate some potential effects of climate change on the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera*. *E. pacifica* spawning is strongly associated with the timing of the onset of upwelling but not with upwelling strength. Spawning peaks four months after the spring transition and juveniles appear two months later. In 2005 upwelling was delayed and krill spawning was similarly delayed. Survivorship of larvae produced that summer was considerably lower than during other years. *T. spinifera* spawn prior to and during upwelling and seem to be more strongly affected by water temperature. 2002 was an anomalously cold year and *T. spinifera*, usually a shelf species, were found far offshore. Their reproductive effort in 2002 was the highest seen during this study. *E. pacifica* were not strongly affected by temperature variations and were always present. *T. spinifera* were rare or absent during warmer ocean conditions. Changes in the timing of the spring transition are likely to affect *E. pacifica* spawning behavior. Consistently warmer ocean temperatures will likely lead to a decrease in *T. spinifera* abundance and spawning. Both scenarios will affect the availability of euphausiids as a food source for higher trophic level predators.

**B1-6067**

## Long-term changes in fish larvae in the northern California Current in relation to climate variability

Toby D. Auth[1], Richard D. Brodeur[2], Heather L. Soulen[1], Lorenzo Ciannelli[3] and William T. **Peterson**[2]

[1] Cooperative Institute for Marine Resources Studies, Oregon State University, Hatfield Marine Science Center, 2030 Marine Science Dr., Newport, OR, 97365, USA
[2] Northwest Fisheries Science Center, NOAA Fisheries, Hatfield Marine Science Center, 2030 Marine Science Dr., Newport, OR, 97365, USA. E-mail: rick.brodeur@noaa.gov
[3] College of Oceanic and Atmospheric Sciences, Oregon State University, 104 COAS Administration Bldg., Corvallis, OR, 97331, USA

We conducted a statistical analysis of the relationships between larval fish concentrations and community structure and both large-scale and local environmental factors to assess the effect of climate change on larval fish in the northern California Current (NCC) in the northeastern Pacific Ocean. Larval fish concentration and taxon composition data were from samples collected at two nearshore stations along the Newport Hydrographic (NH) line off the coast of central Oregon, USA. Data from 1996-2005 were compared with historical data from the 1970s and 1980s to evaluate pseudo-decadal, annual, and seasonal variability. Our results indicate that the most abundant taxa from 1996-2005 differ from those of earlier decades. Concentrations of the dominant taxa and total larvae were generally greater in the winter/spring than summer/fall season. Climate indices, such as Pacific Decadal Oscillation (PDO), Northern Oscillation Index (NOI), and the Multivariate ENSO Index (MEI) and local environmental factors, such as upwelling, Ekman transport, and wind stress curl were related to observed changes in ichthyoplankton concentrations (based on generalized additive modeling) with lag periods ranging from zero to seven months for the various environmental variables. We found that the large-scale climate indices explained more of the variance in overall larval fish concentration and diversity, as well as that of the dominant taxa, than did the more local factors. Our results indicate that readily-available oceanographic and climate indices can explain variations in the dominant ichthyoplankton taxa in the NCC.

**B1-6091**

## Seasonal change in species composition of hydromedusae and the effect of environmental change in Onagawa Bay, northeastern Japan

Genta Takeda, Yoshinari **Endo** and Waka Sato-Okoshi

Laboratory of Aquatic Ecology, Graduate School of Agricultural Science, Tohoku University, 1-1 Amamiya-machi, Tsutsumi-dori, Aoba-ku, Sendai, 981-8555, Japan. E-mail: yendo@bios.tohoku.ac.jp

We investigated the seasonal change in species composition and abundance of hydromedusae in Onagawa Bay for three years from December 2006 to November 2009. Among 26 species that occurred in this study, only 7 were collected every year; *Obelia* spp., *Euphysa aurata*, *Clytia* spp., *Proboscidactyla flavicirrata*, *Muggiaea atlantica* and *M. spiralis*. They also appeared in almost the same season every year, which suggests that their life cycle is completed in the bay. In contrast, species that occurred only in a specific year are thought to have been transported from offshore, including warm-water species such as *Proboscidactyla ornata* and *Podocoryne minima*, whose occurrence are reported in lower latitudes. These species seem to have been transported by a warm-core ring that stayed close to the bay in 2007. Such anomalous oceanographic conditions has the potential to change species composition drastically in the bay. *Obelia* spp., the most dominant species, formed three peaks of abundance every year; winter, spring, and autumn. Based on water temperature at the peak occurrence and morphological features of gonads of mature medusae, the *Obelia* species that formed peaks in winter and spring seems to be *O. longissima* and the autumn medusae are thought to be a different *Obelia* species. The spring peak of *O. longissima* in 2007 was quite high and seems to be caused by higher water temperatures due to the earlier cessation of cold Oyashio water inflow than during other years. We will discuss implications for changes in species assemblages of hydromedusae in the future as water temperatures increase.

**B1-6100**

## Ecosystem implications of the recent southward shift of key components in the southern Benguela

Kate E. **Watermeyer**[1], A. Jarre[1], L.J. Shannon[1] and Larry Hutchings[1,2]

[1] Marine Biology Research Institute, Dept. of Zoology, University of Cape Town, Rondebosch, 7701, South Africa
E-mail: kwatermeyer@gmail.com
[2] Marine and Coastal Management, Private Bag X2, Rogge Bay, 8012, South Africa

The southern Benguela system can be divided into two regions: the west coast system characterised by seasonal, wind-driven upwelling, and the south coast, which includes the Agulhas Bank and thus has characteristics of both a shelf system and an upwelling system. Over previous decades, a number of commercially and ecologically important species (sardine, anchovy, rock lobster and horse mackerel) have undergone southward/ eastward shifts in their distributions. This has had numerous known and countless unknown biological implications for trophically linked species, as well as sometimes severe economic implications for the industries involved. This project aims to investigate possible ecosystem-level impacts of these shifts, and of any changes in physical variables in the southern Benguela, on the biological components of both the ecosystem as a whole and of the south coast subsystem, now playing a more important role both commercially and biologically. Data-derived indicators will be compiled, including indicators of spatial overlap, and ultimately used to drive a frame-based model to be developed as a tool for further exploring the nature of this shift in sardine distribution and to better understand the processes affected.

**B1-6125**

## Effect of water masses on larval fish distribution during the summer SW monsoon in Taiwanese waters, western North Pacific

Wen-Tseng **Lo**[1], Hung-Yen Hsieh[1,2], Dong-Chung Liu[3] and Wei-Cheng Su[3]

[1] Institute of Marine Biotechnology and Resources, National Sun Yat-sen University, Kaohsiung, Taiwan 804, ROC
E-mail: lowen@mail.nsysu.edu.tw
[2] Coastal and Offshore Resources Research Center, Fisheries Research Institute of the Council of Agriculture, Executive Yuan, Kaohsiung, Taiwan 806, ROC
[3] Fisheries Research Institute of the Council of Agriculture, Executive Yuan, Keelung, Taiwan 202, ROC

The spatial distribution patterns of larval fish assemblages and the relationships with hydrographic conditions in Taiwanese waters were studied in August 2004 when the southwesterly monsoon prevailed. A total of 6566 larval fishes were identified, belonging to 80 families, 129 genera, and 230 species. Cluster analysis revealed two station groups, one associated with the South China Sea Surface Current (SCSSC) and the other with the Kuroshio Current (KC). The SCSSC group was characterized by mostly coastal and neritic species, and the KC group was predominated by oceanic species. Larger larval fishes were generally more abundant in the neritic waters west of Taiwan where the SCSSC prevails than in the waters east of Taiwan where the KC prevails. The combination of chlorophyll *a*, zooplankton, and nitrite best explained the relationship of larval fish distributions and environmental variables, implying that the distributions of larval fish in summer were closely linked to food source. The changing of monsoons potentially affects the succession of water masses and the transport and assembly of larval fish species in this study area.

**B1-6170**

## Ecosystem responses to ocean stratification and early-bloom occurrence in the future western subarctic North Pacific: A speculation from retrospective analyses

Tsuneo **Ono**[1], Kazuaki Tadokoro[2] and the A-line Monitoring Team[3]

[1] Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsurakoi, Kushiro, 085-0802, Japan
E-mail: tono@fra.affrc.go.jp
[2] Tohoku National Fisheries Research Institute, Fisheries Research Agency, 3-27-5 Shinhama-cho, Shiogama, 985-0001, Japan
[3] Hokkaido National Fisheries Research Institute and Tohoku National Fisheries Research Institute, Fisheries Research Agency, Japan

Several ecosystem models predict that both the enhancement of upper-ocean stratification and the advancement of spring bloom initiation will occur in the future western subarctic North Pacific. However, integrated impact of these two processes to the oceanic ecosystem had not been precisely investigated. Based on a 50-year retrospective analyses of the oceanic environment and zooplankton stock in the western subarctic North Pacific region, we found that both of these two processes, upper-ocean stratification and early-blooming trends, had previously existed in this region during the period from the 1960s to the present.

Time series analyses of several lower-trophic level ecosystem parameters showed that: 1) Enhanced stratification caused decrease of mixed-layer nutrient content just before the spring bloom, and this lead to declining net primary production and phytoplankton abundance during the spring bloom; 2) Reduced size of spring bloom led to enhanced zooplankton mortality rate in the post-bloom seasons, but advancement of the spring bloom initiation improved food availability of the early-spring seasons.

Zooplankton response against these oceanographic changes, therefore, varied with species depending on the relative importance of early- and post-bloom food conditions in their life cycle. It is not clear that these changes are the direct reflection of past global warming, but observed ecosystem changes associated with these past trends provide us with some indication of future responses to predicted climatic metamorphoses.

**B1-6175**

## Time series observations of chlorophyll fluorescence along the Kuroshio Extension by profiling floats

Sachihiko **Itoh**, Ichiro Yasuda, Tohru Ikeya and Haruka Nishikawa

Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
E-mail: itohsach@ori.u-tokyo.ac.jp

Three profiling floats equipped with a fluorescence sensor were deployed in May 2008 around the axis of the Kuroshio, near its separation point from the continental shelf and they moved eastward with upper-layer flows to the Kuroshio Extension region. The floats were designed to park at 40 m depth and measure temperature, salinity, and in vivo chlorophyll fluorescence profiles from the surface to 500 db depth every 5 days. Chlorophyll fluorescence measurements continued for more than 1 year by two of the floats, as they migrated along the northern and southern flanks of the Kuroshio Extension, respectively. For both of these floats, seasonal variation in chlorophyll fluorescence basically reflected that of mixed layer depth, while shorter-term fluctuations occurred, possibly reflecting short-term atmospheric forcing or frontal disturbances of the Kuroshio Extension, or both. This short-term fluctuation showed larger amplitude in the northern flank than in the southern flank throughout the year. Discussion will be made on food availability of larval Japanese sardine and Japanese anchovy, which are suggested by recent studies to be critical for the recruitment success of these species.

**B1-6223**

## Long-term temporal trends in ichthyoplankton community composition in the southern California Current System

Andrey **Suntsov** and Tony Koslow

Scripps Institution of Oceanography, 9500 Gilman Dr., La Jolla, CA, 92093-0218, USA. E-mail: tkoslow@ucsd.edu

Long-term monitoring of the southern California Current System, carried out by the California Cooperative Fisheries Investigations (CalCOFI) since 1951, provides a unique opportunity for documenting changes in pelagic communities. We examined decadal-scale variability in ichthyoplankton community composition using several multivariate approaches based on total area-averaged larval densities of 112 representative taxa recorded during 1951-2007 (44 years). Cluster analysis revealed that the principal change in the larval fish community closely matched the regime shift observed in the late 1970s, with the 1951-1969 period clearly distinct from 1984-2007. Of the 50 mesopelagic taxa used in the analysis, 43 increased in abundance during 1984-2007 *vs.* 1951-1969, mostly represented by species with central gyre and southern affinities, while cold-water midwater species (*e.g. Tarletonbeania crenularis, Stenobrachius leucopsarus*) or non-migrating species (*Cyclothone* spp.) were more abundant during earlier (colder) decades. *Sardinops sagax, Vinciguerria lucetia, Merluccius productus* and *Lipolagus okhotensis* were the primary species contributing to the changeover to warm-regime communities, and *Engraulis mordax, Trachurus symmetricus* and *Leuroglossus stilbius* were primarily favored during cold periods. We used non-metric multidimensional scaling and principal component analysis to explore additional temporal patterns not revealed by one-dimensional cluster analysis, as well as to examine species responsible for minor variations in community composition. In this presentation we will detail how oceanographic conditions in the southern California Current may have influenced the structure of ichthyoplankton community over the last six decades and how species with differing ecological affinities show a range of responses to both short and long-term climate variability in the region.

**B1-6238**

## Uncertain future of fish populations in Argentinean coastal lakes: The impact of severe droughts and floods

Rubén J. **Lara**[1], Germán A. Kopprio[1], Carlos A. Strüssmann[2] and Hugo Freije[3]

[1] Wetland Biogeochemistry, Leibniz Center for Tropical Marine Ecology, Fahrenheitstrasse 6, 28359 Bremen, Germany
E-mail: ruben.lara@zmt-bremen.de
[2] Marine Biosciences, Tokyo University of Marine Science and Technology, Konan 4-5-7, Minato-ku, Tokyo, Japan
[3] Environmental Chemistry, Universidad Nacional del Sur, Av. Alem 1253, B8000CPB Bahía Blanca, Argentina

Climate change impacts fish dynamics and represents a challenge of faster thermal adaptation for South American fish. The Argentinean pampas had registered increasing rainfall and severe floods during the last 3 decades. However, since 2007 a rigorous drought has affected the region. Chasicó Lake belongs to an endorreic basin particularly sensitive to hydrologic alterations, responding with dramatic changes in extension and salinity. In 1963, Chasicó was a hypersaline water body of ~3000 ha, devoid of fish due to salinities of ~100 g $L^{-1}$. After the floods, it expanded to ~12,000 ha and salinity decreased to ~20 g $L^{-1}$. *Odontesthes bonariensis* entered the lake through Chasicó River after the inundations and found the moderate salinities that favor its growth at early development stages. This resulted in a drastic increase of fish size and stock over a few years, and shifts in human stakeholder structure. During the current dry phase, 2009 underwent the worst drought of the last 7 decades. This worsened the natural eutrophic state of pampean water bodies and increased their salinity. Particularly in the shallower lakes, severe fish mortalities occurred, likely due to high temperature, anoxia, toxic cyanobacteria blooms, or some combination of these. During 2007 and 2008 the water level in Chasicó decreased about 1 meter and salinity increased to 23 g $L^{-1}$. The sensitive response of this ecosystem to the changing character of droughts and inundations predicted for the late 20$^{th}$ century illustrates its potential as an indicator of future coastal changes that could generate new risks or opportunities for fish populations and society.

**B1-6274**

## Studies on the hydrobiology of the coconut husk retting grounds in the AVM Canal in Thoothoor region, southwest coast of India

Sekharapilla **Premjith**

Department of Advanced Zoology and Biotechnology, St. Jude's College, M.S. University, Thoothoor, Tamilnadu, 629176, India
E-mail: drpremjith@rediffmail.com

The present investigation pertains to the environmental and faunal characteristics of three selected stations within the Anantha Victoria Marthanda Varma (AVM) Canal along the Thoothoor coast, which is polluted by coconut husk retting activity. Physico-chemical parameters were studied along with plankton and nekton and results were presented. A seasonal pattern of phytoplankton group was lacking in the present study. Algal blooms have not been observed during any time of the year, but a seasonal variation of zooplankton was observed in the present investigation. The fish larvae in the present study - the icthyoplankton of the zooplankton community - occurred only in non-retting zones. Only two species of fish were conspicuous at all stations during all seasons. The overall fish production from the system has declined as a result of retting pollution. The discharge of pollutants into natural water resources results in the deterioration of the physical, chemical, and biological qualities of water. The pollution has highly toxic effects on the growth of various planktonic and nektonic organisms, and causes depletion of oxygen. These organisms can act as important indicators of pollution in fresh water and brackish water bodies.

**B1-6333**

## Early life history of *Euphausia pacifica* in the western North Pacific

Yuji **Okazaki** and Kazuaki Tadokoro

Tohoku National Fisheries Research Institute, FRA, 3-27-5 Shinhama-cho, Shiogama, Miyagi, 985-0001, Japan
E-mail: okazakiy@affrc.go.jp

Euphausiids often play a key role in food webs because of their trophic position between primary producers and fishes or marine mammals. Thus, their biological and ecological responses to climate change are important for marine ecosystems and fisheries. In the western North Pacific, *Euphausia pacifica* is the most abundant euphausiid, and thus are key species in the ecosystem. However, changes in the biology and ecology of *E. pacifica* in relation to climate change are poorly known in the western North Pacific because long-term data on this species are very limited. On the other hand, previous work indicated that springtime abundance of *E. pacifica* eggs and larvae correlated well with their adult abundance during summer-autumn. This result implies that interannual variation in abundance of early stages of *E. pacifica* could be a good indicator of their long population changes. This variation can be examined over the long term because eggs and larvae are easily sampled by small plankton nets such as the NORPAC net, which has been used to collect samples since the 1950's. To explore this possibility, we investigated the spatial and seasonal distribution of *E. pacifica* larvae in the western North Pacific using BONGO nets (0.33mm mesh size with 0.6m diameter) and NORPAC nets (0.33mm mesh size with 0.45m diameter). In 2006 and 2007, BONGO nets captured *Calyptopsis* spp. and *Furcilla* spp. throughout year, especially during spring. This seasonal pattern well corresponds to spring bloom.

**B1-6382**

## Climate and fishing pressure drive a non stationary behaviour in the long-term changes of pelagic food webs in European Shelf Seas

Juan Carlos **Molinero**[1], Michele Casini[2], Jakov Dulcic[3], Branka Grbec[3], Manuel Hidalgo[4], Lyudmila Kambourska[5], Andreas Lehman[1], Marcos Llope[4] and Mira Morovic[3]

1 Leibniz Institute of Marine Sciences, IFM-GEOMAR, Düsternbrooker Weg 20, Kiel, 24105, Germany
E-mail: jmolinero@ifm-geomar.de
2 Swedish Board of Fisheries, Institute of Marine Research, Box 4, Lysekil, 54321, Sweden
3 Institute of Oceanography and Fisheries, Setaliste Ivana Mestrovica 63, Split, 21000, Croatia
4 Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biology, University of Olso, P.O. Box 1066 Blindern, Oslo, 0316, Norway
5 Joint Research Centre (EC-JRC), Ispra, 21020, Italy

Quantifying the extent to which the interactions between plankton and fish, and potential trophic cascades, are driven by anthropogenic or climate forcing, or their synergies, is crucial to develop an ecosystem approach to fisheries management in a changing world ocean. In this study, we used a combined approach based on regional climatology, time series analysis and meta-analysis techniques of ecological data to investigate the response of pelagic food webs, from primary producers to fish, to fishing pressure and climate-related stressors in European shelf seas. The quantitative synthesis allows identifying the transient dynamics and leading linkages between climate, plankton and fish, whose long term variability reveals periods of coupled and uncoupled changes emphasizing a non-stationary behavior. We show that over the second half of the twenty century, extreme climate events have triggered coherent changes, despite reductions in fishing pressure, in pelagic food webs regardless of longitudinal (*i.e.* oceanic connectivity) and latitudinal (*i.e.* temperature) gradients of the European Shelf Seas. These results indicate that sound actions for European marine resources require fundamentally a regional coordinated framework.

**B1-6415**

## Identification of the relationship between environmental features and copepod abundances in the Kuroshio waters adjacent to eastern Taiwan using generalized additive models

Yu-Kai **Chen**[1], Yi-Jay Chang[2], Chi-Lu Sun[2], Chi-Lun Wu[1], Dong-Chung Liu[1] and Wei-Cheng Su[1]

1 Fisheries Research Institute, Council of Agriculture, Executive Yuan, Keelung, Taiwan, 20246, ROC. E-mail: ykchen@mail.tfrin.gov.tw
2 Institute of Oceanography, National Taiwan University, Taipei, Taiwan, 10617, ROC

Spatial distribution patterns of copepod abundances were analyzed in relation to environmental variables in the Kuroshio waters adjacent to eastern Taiwan. Generalized additive models (GAMs) were applied to examine the relative influence of environmental factors on copepod abundance in this region. Data for the analysis were collected during quarterly cruises of the TaiCOFI program from 2005 to 2008. To construct a GAM, relationships between environmental variables (season, chlorophyll *a* concentration, temp. at 5 m, temp. at 100 m, temp. differences between 5 m and 100 m, salinity at 5 m) and copepod abundances were analyzed. Stepwise GAM building revealed the relative importance of the variables in explaining the variance in copepod abundance. The variables ranked (1) season, (2) Chl-*a* concentration, (3) temp. at 100 m, (4) salinity at 5 m, (5) temp. at 5 m and (6) temp. differences between 5 m and 100 m in decreasing order. Time series of copepod abundance standardized for physical and biotic factors quantified in the GAM showed that the spatial pattern of copepod abundance was characterized by noticeable high abundances associated with higher chlorophyll *a* concentration, lower temperature at 5 m and lower salinity at 5 m in the northwestern (121.5~122°E, 23.5~24.5°N) and southwestern (121~121.5°E, 22~23°N) nearshore region of the study area.

# B2 Oral Presentations

**28 April, 9:05 (B2-6213), Invited**

## Changes in productivity of marine ecosystems from low to high latitudes under climate variability and change

Svein **Sundby**

Institute of Marine Research, P.O. Box 1870 Nordnes, Bergen, 5817, Norway. E-mail: svein.sundby@imr.no

The world oceans comprise a large diversity of marine ecosystems where key populations have developed a large diversity of adaptations to physical forcing. Moreover, the critical physical processes for productivity vary between marine ecosystems. Together, these factors generate large differences in how energy propagates from primary production to higher trophic levels. Climate change in the ocean will, therefore, has no uniform impact on the productivity of different marine ecosystems, but will differ widely, depending on structure and function. Examples of responses in subtropical ecosystems, upwelling ecosystems, high-latitude shelf systems, high-latitude oceanic ecosystem, and Arctic ecosystems are given. On the large scale, a general displacement of species towards higher latitudes is expected to occur as a result of global warming. But on the regional scale, more complicated responses will occur because of specific interactions of species with different physical constraints. Decadal and multidecadal climate oscillations in the North Atlantic during the 20th century have given us some indications on how populations and marine ecosystems respond to climate variability of different periodicity. Persistent climate signals have different impacts than climate signals of shorter periodicity.

**28 April, 9:30 (B2-6225)**

## On the utility of self-organizing maps (SOM) and k-means clustering to characterize and compare low frequency spatial and temporal climate impacts on marine ecosystem productivity

Jae Bong Lee[1] and Bernard A. **Megrey**[2]

[1] National Fisheries Research and Development Institute, 408-1 Shirang-ri, Gijang, Busan, 619-905, R Korea
[2] NOAA, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115, USA
E-mail: Bern.Megrey@noaa.gov

Temporal and spatial patterns of recruitment (R) and spawning stock (S) variability from 17 stocks were compared among functionally analogous species and similar feeding guilds from six marine ecosystems. Data were aggregated into four regions, including the Gulf of Maine/Georges Bank, the Norwegian/Barents Seas, and the eastern Bering Sea and the Gulf of Alaska. Self organizing maps (SOM) and k-means clustering were used to examine patterns of synchrony and asynchrony in recruitment and spawning stock indices among and between ecosystems, between- and within-ocean basins, among functionally analogous species groups and among large-scale atmospheric indices. Time series trends in the ln(R/S) response variable showed consistent within-basin similarities and consistent and coherent differences between the Atlantic and Pacific basin ecosystems. SOMS and k-means clustering provide a highly visual tool to easily identify patterns in the timing of high or low productivity years across both species and ecosystems. Many of the peaks in the time series were synchronous within an ocean basin and opposing alternations in patterns of productivity were observed in ecosystems in between the Atlantic and Pacific Ocean basins. The data suggest common external factors act in synchrony on stocks within ocean basins but temporal stock patterns, often of the same species or functional group, between basins change in opposition to each other. Basin-scale results (similar within but different between) suggest that productivity in the two geographically broad areas are connected by unknown climatic mechanisms that, depending on the year, generate low frequency opposing alternations in the two basins.

**28 April, 9:45 (B2-6278)**

## Marine climate change impacts: Out of sight but not out of mind

Elvira S. **Poloczanska**[1], Keith Brander[2], Chris Brown[1,3], John Bruno[4], Lauren Buckley[5], Michael T. Burrows[6], Carlos Duarte[7], Pippa Moore[8], Mary O'Connor[9], John Pandolfi[10], Camille Parmesan[11], Maria Sanchez-Camacho[7], David Schoeman[12], William J. Sydeman[13] and Anthony J. Richardson[1,14,15]

1 Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, P.O. Box 120, Cleveland, QLD, 4163, Australia
E-mail: Elvira.Poloczanska@csiro.au
2 National Institute of Aquatic Resources, Technical University of Denmark, Charlottenlund Slot, Jægersborg Allé 1, Charlottenlund, Denmark
3 Spatial Ecology Lab, The University of Queensland, Brisbane, QLD, 4072, Australia
4 The University of North Carolina at Chapel Hill, Department of Marine Sciences, Chapel Hill, NC, 27599-3300, USA
5 The University of North Carolina at Chapel Hill, Chapel Hill, NC, 27599-3280, USA
6 Scottish Association of Marine Science, Dunstaffnage Marine Laboratory, Oban, Argyll, PA37 1QA, UK
7 Instituto Mediterráneo de Estudios Avanzados (IMEDEA), C/Miquel Marqués 21, 07190 Esporles (Mallorca), Spain
8 Centre for Marine Ecosystems Management, Edith Cowan University, 270 Joondalup Dr., Joondalup, WA, 6027, Australia
9 National Center for Ecological Analysis and Synthesis, 735 State St., Suite 300, Santa Barbara, CA 93101, USA
10 Centre for Marine Studies, School of Earth Sciences, and ARC Centre of Excellence for Coral Reef Studies, The University of Queensland, Brisbane, QLD, 4072, Australia
11 University of Texas, Integrative Biology, 1 University Station C0930, Austin, TX, 78712, USA
12 School of Environmental Sciences, University of Ulster, Coleraine campus, Cromore Rd., Coleraine, Co. Londonderry, BT52 1SA, UK
13 Farallon Institute for Advanced Ecosystem Research, P.O. Box 750756, Petaluma, CA, 94975, USA
14 University of Queensland, School of Mathematics and Physics, St. Lucia, QLD, 4072, Australia
15 The Ecology Centre, The University of Queensland, St. Lucia, QLD, 4072, Australia

Climate change is impacting our global biodiversity. The IPCC 4th Assessment Report reported 28,671 significant biological changes globally of which 90% were consistent with climate change. Few were from the Southern Hemisphere, which may be attributed to a lack of studies at regional or national scales. In addition, less than 0.3% of these biological changes were from marine systems. This fundamental information is critical for developing integrated and adaptive management strategies to protect marine environments and fisheries in the future. We aim to address key questions concerning the vulnerability of marine systems to climate change such as: Which marine species, taxonomic groups and systems (*e.g.*, pelagic, benthic, rocky shore, sandy beach, coral reef) are most sensitive? What are the similarities and differences in the types and rates of responses in tropical, temperate and polar seas? To what extent do human stressors such as fishing increase vulnerability of species and habitats to climate change? To address these questions, we are building a marine climate impacts database employing an innovative tiered approach to classify impacts which will cover the peer-reviewed literature as well as the grey literature where many valuable fisheries studies are found. Evidence suggests responses from marine systems, in terms of distribution and phenological shifts, may be faster than from land systems. Preliminary results from the database will be presented. We encourage researchers to submit their papers and reports for inclusion; the database will eventually be publicly-accessible through the National Center for Ecological Analysis and Synthesis (USA) data repository.

**28 April, 10:00 (B2-6261)**

## Potential impacts of climate change on Northeast Pacific marine ecosystems

Thomas A. Okey[1,2], Jameal F. **Samhouri**[3], Cameron H. Ainsworth[3], D. Shallin Busch[3] and William L. Cheung[4]

1 West Coast Vancouver Island Aquatic Management Board, 3-4310 10th Ave., Port Alberni, BC, V9Y 4X4, Canada
2 University of Victoria School of Environmental Studies, Victoria, BC, V8P 5C2, Canada
3 NOAA-Fisheries, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA, 98112, USA
E-mail: jameal.samhouri@noaa.gov
4 University of East Anglia, School of Environmental Sciences, Norwich, NR4 7TJ, UK

We assembled a set of Ecopath with Ecosim models to explore the impacts of climate change on various indicators of ecosystem structure and function in the Northeast Pacific Ocean. The effects of projected future changes in primary productivity on marine biological communities of Australia was recently explored using a set of Ecopath with Ecosim models from that region, with indications of increased Australian fisheries production related to those projected changes. In addition to differences in primary production, several other dimensions of oceanographic change may prove equally, if not more, important in shaping future ecological communities. These include effects of temperature on species' bioenergetic rates and biogeographic ranges, effects of ocean acidification on

species survival and productivity, and effects of declining oxygen concentrations on mortality rates of sessile species. Ocean temperature and acidification are predicted to increase in the Northeast Pacific region based on oceanographic modeling, and the frequency of low dissolved oxygen events will likely increase as well. The goal of the present exploration was to model the combined effects of climate-induced changes in at least temperature and pH on fisheries landings, fisheries value, community biomass, diversity, mean trophic level, and other ecosystem characteristics.

**28 April, 10:15 (B2-6244)**

## Ecosystem response to future climate change in the Northeast Atlantic: Results from the RECLAIM Project

Kenneth **Drinkwater**[1] and the RECLAIM Team

[1] Institute of Marine Research, P.O. Box 1870 Nordnes, Bergen, N5817, Norway. E-mail: ken.drinkwater@imr.no

Comparisons of the expected ecosystem responses to future climate change in the Northeast Atlantic from the Barents Sea south to the Bay of Biscay, and including the Baltic Sea, will be presented based upon results from the recently completed RECLAIM (Resolving CLimAtic Impacts on fish stocks) Project. In addition to examining similarities and differences in the latitudinal responses, consideration will also be given to the differences between the near coast, shelf and the open ocean. Lacking downscaled regional models for most of the study areas, results from some "what if" scenarios will be presented. Following discussion of projected changes in the physical oceanography of the various regions, comparison of the possible changes in the phytoplankton and zooplankton production and timing will be given. A major emphasis of the talk will be on the expected changes to the major fish stocks, especially how and why the responses differ in the different regions. This will include changes in production, recruitment, distribution, migration patterns, and phenology. In addition, a discussion of the requirements to improve future ecosystem projections that will emphasize the need for improved regional models and quantitative measures of uncertainty in the projections will be highlighted.

**28 April, 10:30 (B2-6188)**

## Are general mechanisms found behind regime shifts across marine ecosystems?

Susa **Niiranen**[1,2], Thorsten Blenckner[1] and Reinette Biggs[3]

[1] Baltic Nest Institute, Stockholm Resilience Centre, Stockholm University, Stockholm, SE-106 91, Sweden
E-mail: susa.niiranen@stockholmresilience.su.se
[2] Department of Systems Ecology, Stockholm University, Stockholm, SE-106 91, Sweden
[3] Stockholm Resilience Centre, Stockholm University, Stockholm, SE-106 91, Sweden

During the last decade a number of studies on regime shifts in various marine ecosystems have been published with a number of different regime-shift detection methods. We address the use of various methods and assess the comparativeness between studies based on a representative collection of regime-shift descriptions published across marine ecosystems. Mapping the different methods and combining this knowledge with the data produced is a necessary step towards studying the potential to quantify marine regime shifts on a global scale. We will also compare the effects that single (*e.g.*, climate or fishery) and multiple regime-shift drivers have had on the threshold, timing and/or amplitude of the ecosystem shift in the various ecosystems. This information is required for the adaptation of human practices, such as fishery quotas, to accommodate the future changes in climate. Most importantly, the published marine ecosystem regime-shift studies seldom touch upon the mechanisms of change and feedback loops related, but focus on describing the amplitudes, new regime periods and main causal drivers. We hypothesize that general mechanisms and feedback loops are behind regime shifts detected across different ecosystems, potentially even behind shifts brought up by differing drivers. Hence, to fill in the knowledge gap we aim to identify these central mechanisms from regime shifts documented on well-studied ecosystems such as the Baltic Sea, Black Sea, North Sea and Japan/East Sea. Identifying common key mechanisms would increase the predictability of potential future shifts and potentially facilitate their mitigation.

**28 April, 11:05 (B2-6054), Invited**

## Housing crisis: Climate change-induced habitat loss impacts on temperate and tropical fishes

Nicholas K. **Dulvy**

Earth to Ocean Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, BC, V5A 1S6, Canada
E-mail: dulvy@sfu.ca

Climate change is rapidly warming the oceans, reducing fish habitat which, in turn, influences fish community structure. I show how this plays out both in temperate demersal fish assemblages and coral reef fish assemblages. North Sea winter bottom temperature has increased by 1·6°C over 25 years; this has eliminated cold water habitat (isotherms) and has led to the expansion of the areal extent of warm water habitats. This has resulted in incoherent latitudinal shifts and a coherent deepening of the whole demersal fish assemblage. The incoherent latitudinal range shifts result from the peculiarities of local bathymetry and hydrography which modulate regional warming to produce southward distributional shifts that are consistent with anthropogenic climate change. In contrast to the fluid habitats (isotherms) of temperate shelf seas, coral reefs are a key static habitat in tropical coastal seas. Coral reefs are suffering unprecedented rates of coral mortality and architectural collapse due to a range of direct climate impacts and indirect fishing related impacts. The architectural complexity of coral reefs underpins species coexistence: complex reefs support a greater diversity of reef fishes and longer food chains. I unveil the collapse of Caribbean reefs and examine the drivers, non-linearity and lags in the collapse of Caribbean reef habitat. Finally, I examine how climate-induced coral reef habitat losses impact reef fish communities in Fiji.

**28 April, 11:30 (B2-6043)**

## Spatial and interannual variability in oceanography, plankton and forage fish in the Bering Sea: Results from U.S. BASIS surveys for 2002-2008

Lisa B. **Eisner**[1], Seth Danielson[2], Edward W. Farley[1], Jeanette Gann[1] and Markus Janout[1]

[1] Ted Stevens Marine Research Institute, Alaska Fisheries Science Center, NOAA Fisheries, 17109 Point Lena Loop Rd., Juneau, AK, 99801, USA. E-mail: lisa.eisner@noaa.gov
[2] School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 114 O'Neill Bldg., Fairbanks, AK, 99775-7220, USA

Oceanographic and fisheries data were collected during late summer/early fall in the eastern Bering Sea (EBS) on U.S. BASIS (Bering Aleutian Salmon International Survey) cruises during 2002-2008. We describe variations in nutrient and chlorophyll *a* concentrations, zooplankton taxonomic composition and diets of forage fish (*e.g.* juvenile salmon, pollock) in relation to physical oceanographic conditions for warm and cold years. Our analysis includes comparisons between the southern and northern Bering Sea. The southern area was characterized by higher temperature (T) and salinity (S), greater vertical stability and greater interannual variation in T, reflecting interannual variations in sea ice extent. In contrast, the northern area showed lower T and S (more freshwater), stronger cross-front gradients, greater mixed layer depths, and high beam attenuation (more particles in the water). These data provide further evidence for the importance of pelagic food webs in the south and benthic food webs in the northern Bering Sea. Temperature and zooplankton distributions varied between warm (2002-2005) and cold (2006-2008) years with larger copepods (*e.g. Calanus marshallae*) seen on the EBS shelf in years with lower mean water T and an extensive near-bottom cold pool (T < 2°C). This analysis helps to link habitat and zooplankton prey availability with abundance, distribution and fitness of forage fish prior to winter, and provides information on the underlying oceanographic processes affecting the EBS ecosystems and potential responses to climate fluctuations.

**28 April, 11:45 (B2-6012)**

## Climatic trends and long-term changes in species composition and abundance of pelagic fishes along the Sakhalin coast in the Japan Sea and the Okhotsk Sea

Anatoliy Ya. **Velikanov**

Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO), 196 Komsomolskaya St., Yuzhno-Sakhalinsk, 693023, Russia
E-mail: velikanov@sakhniro.ru

Along both the western and eastern Sakhalin coasts, the frequency of major non-abundant south-latitude fishes increased during the years when the intensity of the Tsushima Warm Current was high (1947-1949; 2002-2008). Seasonal migrations of Pacific sardine and Japanese anchovy in the same areas have been observed mainly in years with an opposite climatic mode. A similar change in abundance has been observed for the basic cold-water fish species that spawn in winter-spring and summer-autumn seasons. In the 1970s-1980s, when the intensity of the Tsushima Current was low, a relatively high abundance was common for populations of walleye pollock, herring, capelin and other species which reproduce during the winter-spring period. In the late 1980s and in the 1990s, the intensity of the Tsushima Current increased, but the stocks of the above-mentioned species were considerably reduced. However, fish species, which spawned in summer and autumn, on the contrary, essentially increased in numbers. Under similar general trends, abundance dynamics of the major fish species along western and eastern Sakhalin had certain differences. For example, a period of high abundance for herring, pollock, sardine and arabesque greenling populations was longer in the Okhotsk Sea, whereas for anchovy and pink salmon in the Tatar Strait. In 1950-2008, opposite-directed trends have been observed for pink salmon annual catch dynamics along western and eastern Sakhalin. It is obvious that spatial-temporal responses of marine ecosystems to climatic mode shifts in the Japan Sea and southwestern part of the Okhotsk Sea differ according to their specific characteristics.

**28 April, 12:00 (B2-6296)**

## Response of dominant species in coastal and oceanic regions of Peru

Miguel **Ñiquen** and Cecilia Peña

Pelagic Resource Area, Instituto del Mar del Perú (IMARPE), Gamarra y General Valle s/n Chucuito, Apartado 22, Callao, Lima, Perú
E-mail: mniquen@imarpe.gob.pe

Well known is the spatial and temporal nearshore interaction in Peruvian waters of the anchovy (*Engraulis ringens*) and sardine (*Sardinops sagax*), but there also exists another spatial interaction between two dominant species: anchovy and lanternfish (*Vinciguerria lucetia*). A key point between both species is that they have similar characteristics such as a short life span, small size, schooling behaviour, high biomass, but they inhabit different regions: anchovy is a nearshore pelagic species while the lanternfish is an oceanic mesopelagic species. The goal of this study is to show that the same climate signal affects the response of resources in different ways, depending on the distribution of the resources.

A comparison of the responses was evaluated during climate extreme phases. The study area corresponded to Peruvian Sea, from 3°30″S to the boundary with Chile, based on research survey data. It was found that in an extreme cold event (La Niña), the anchovy extended its latitudinal and longitudinal distribution while the presence and abundance of lanternfish was notably diminished; on the other hand, in an extreme warm event (El Niño), the latitudinal distribution of anchovy retreated from the north to the central–southern zone and the lanternfish expanded its distribution to nearshore region, mainly in the southern zone due to the lower extension of continental shelf.

Due to the impact of climate variability, we must take account a possible increase in new species associated with Vinciguerria and the future development of new fisheries.

**28 April, 12:15 (B2-6247)**

## The limits for forecasting fish population dynamics under changing climate scenarios: The example of small pelagic fishes

Jürgen **Alheit**

Leibniz Institute for Baltic Sea Research, Seestr. 15, Warnemünde, 18119, Germany. E-mail: juergen.alheit@io-warnemuende.de

Population size of small pelagic fish species, such herring, sprat, anchovy, sardine and sardinella in waters surrounding Europe, has been shown to swing in association with the dynamics of oscillating climate indices, in particular the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO) indices. Whereas the NAO is a decadal-scale atmospheric index, which is based on the difference of atmospheric pressure at sea level between the Icelandic Low and the Azores High, the AMO, a multidecadal-scale oscillating pattern of sea surface temperatures in the Atlantic Ocean, is an oceanographic index. Both oscillations do not swing in synchrony. When comparing reactions of small pelagics since the early 19$^{th}$ century over a range of different ecosystems (coastal, semi-enclosed, shelf, open ocean) to these climatic oscillations, it turns out that they change population size and distribution primarily in association with either the NAO or the AMO. In some cases, both oscillations seem to affect small pelagics populations. It is debated in the climate community whether NAO and AMO dynamics can be predicted. In addition, recent studies suggest that the NAO comprises four different "weather regimes", not only a positive and a negative phase, whereby spatial changes in the location of the Icelandic Low and the Azores High are considered. Consequently, forecasting the size of small pelagic fish populations for the next 5-10 years, as desired by fisheries managers, does not seem very feasible under the climatic conditions described here.

**28 April, 12:30 (B2-6023)**

## Thermal limits and coastal migration of chum salmon (*Oncorhynchus keta*) determined by submesoscale circulation

Konstantin **Rogachev**

Department of Ocean Physics, V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, 43 Baltiyskaya St., Vladivostok, Primorsky Kray, 690041, Russia. E-mail: rogachev@poi.dvo.ru

The upper layer temperature is a primary oceanographic factor influencing the southern limit of Pacific salmon distribution. Thermal boundaries limit the distribution of salmon species in the Pacific Ocean and adjacent seas. This occurs because temperature-dependent metabolic rates exceed energy intake from feeding over large regions. All species of salmon on the route to spawning grounds require pure well-oxygenated cold water. We show that vast regions (Oyashio, and Okhotsk and Bering seas) exhibit a warming trend. This rate of warming is much faster than that of the Global Ocean and the Okhotsk Sea. Adult chum salmon migrate at depth to avoid the high temperature. However, it is impossible to perform such a migration in shallow coastal waters. The coastal ecosystem in the northwestern Sea of Japan serves as a migration route and spawning habitat for wild salmon species. The present study combines satellite data with physical observations to examine physical/biological coupling within this coastal ecosystem. Mesoscale eddies and associated submesoscale filaments are important features of the region. We show significant warming due to the penetration of warm submesoscale filaments. These events establish advection of warm water and determine the thermal limits for species in shallow coastal areas. Water exchange with the slope region determines an unfavorable regime for the spawning migration of salmon species to freshwater. The observed temperature increase will severely restrict the area of their habitat that supports growth and will potentially exclude salmon from their current habitat.

**28 April, 12:45 (B2-6228)**

## Changes in the stock size and life history traits of Japanese common squid *Todarodes pacificus* in relation to climate changes, with special comparison between in the Kuroshio-Oyashio currents region and the Sea of Japan

Hideaki **Kidokoro**[1], Norio Yamashita[2], Tsuneo Goto[1] and Yongjun Tian[1]

[1] Japan Sea National Fisheries Research Institute, Fisheries Research Agency, 5939-22, Suido-cho 1, Niigata, 951-8121, Japan
E-mail: kidokoro@fra.affrc.go.jp
[2] Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsurakoi, Kushiro, 085-0802, Japan

The impact of climatic regime shift (CRS) on the stock size and life history traits of Japanese common squid (*Todarodes pacificus*) was examined, and differences between the Kuroshio-Oyashio currents region and the Sea of Japan were compared. Japanese common squid is distributed in the northwest Pacific, including the Sea of Japan, and is the most important cephalopod species in Japanese and South Korean fisheries. Total annual landings by the Japanese and South Korean fisheries were about 500,000 t during the 1950s and 1960s, but decreased to 200,000 t during the 1970s and 1980s. Landings have rebounded to about 500,000 t in the 1990s. Generally, it is considered that CRS occurred around 1976-1977 (76/77CRS) and 1988-89 (88/89CRS), and SSTs showed negative anomalies during 1977-1988 and have shown positive anomalies since 1989 in the Northwest Pacific. The life history traits of Japanese common squid changed, coinciding with the 88/89CRS, and the stock size increased in both the Kuroshio-Oyashio currents region and the Sea of Japan. However, the stock size of Japanese common squid in the Sea of Japan decreased with a change in life history traits, coinciding with the 76/77CRS, while the stock size in the Kuroshio-Oyashio currents region decreased in the early 1970s. This difference suggests variability in the response of CRSs to the life history traits and stock size of Japanese common squid between the Kuroshio-Oyashio currents region and the Sea of Japan.

**28 April, 13:00 (B2-6397)**

## Coupling between multi-decadal transients in fish stock abundance and anthropogenic forcing

Brian J. **Rothschild**

School for Marine Science and Technology, University of Massachusetts Dartmouth, 706 South Rodney French Blvd., New Bedford, MA, 02744-1221, USA. E-mail: brothschild@umassd.edu

Multi-decadal transients or multi-decadal fluctuations in fish stock abundance can be inferred from readily available time series. The transients are evident both before and after the onset of industrialized fishing and recent phenomena that are thought to be climate change related (*e.g.*, warming, NAO, *etc.*). This observation raises questions concerning the coupling between the transients and natural environmental fluctuations and anthropogenic forcing, including fishing and warming. In order to address these questions in the context of ecosystem response, it is necessary to take into account the relative influence of 1) non-linear population dynamics, 2) fishing, and 3) short- and long-term environmental forcing (*e.g.*, climate) on fish population dynamics. In essence, this amounts to studying the coupling among fish stock dynamics, fishing, and the ocean environment. This paper considers the relative influence of these factors on fish population dynamics. Examples are based upon the increases and decreases of gadoids in the North Sea, the anchovetta off Peru, northern cod, California sardine, Norwegian spring spawning herring, and Pacific salmon, among others. Common elements among the examples include time stanzas within the transients that are coupled with plankton dynamics and not coupled with fishing.

# B2 Posters

### B2-6006

## Short-period variability of oceanologic conditions in the vicinity of the Pulkovskaya seamount (Part I)

Vladimir B. Darnitskiy[1] and Maxim A. **Ishchenko**[2]

[1] Pacific Scientific Fisheries Research Center, P.O. Box 690950, 4 Per., Shevchenko St., Vladivostok, Russia
[2] V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, 43 Baltiyskaya St., Vladivostok, Primorsky Kray, 690041, Russia
E-mail: maksim@poi.dvo.ru; laitik@mail.ru

The geographical position and hydrology near the Pulkovskaya Seamount were discussed earlier (Darnitskiy, 1991). To study the short-period variability of oceanologic processes in the Pulkovskaya Seamount area, the following operations were performed: 1) During a 6-day experiment above the northern summit of the seamount (R/V *Mys Babushkin*, April 22-27, 1980), water temperature, dissolved oxygen, and nutrients (phosphates and silicic acid) were taken at 6-h intervals. Netplankton biomass was also collected to a depth of 100 m during the experiment. 2) A 10-day experiment was carried out at 24-h intervals (*i.e.*, once every 24 h) above the center of the northern summit (R/V *Ekvator*, May 7-16, 1980) in which temperature, salinity and oxygen concentrations were taken. 3) Examination of a 13 mile (21 km) cross-section was repeated 10 times at 24-h intervals (P/V *Charles Darwin*, December 1986). In February-March 1987, examination of the cross-section was repeated three more times at steps of 3 and 4 days over 50 miles (80 km) across the northern top of the Pulkovskaya Seamount. At daily stations, observations were carried out to a depth of 500 m from the summit and over a 1500 m cross-section. Measurements of temperature, salinity, oxygen concentrations, phosphates, silicic acid, and plankton biomass were made to 600 m depth.

During the 6-day observation, the atmospheric pressure varied widely at amplitude of 28 mb (from 989-1017mb). The wind field above the Pulkovskaya seamount was not influenced by the atmospheric pressure, but the air temperature was observed to fall considerably with the decrease in atmospheric pressure. Fluctuations in the mesoplankton biomass occurred mainly on a 24-h cycle. The biomass reached its maximum, 128 mg/cm$^3$, at 10 p.m. local time on April 22 when the temperature of the surface water (11.7°C), oxygen concentrations (6 ml/l) and biogenic elements (22 mkgP/l and 115 mkg Si/l) were at their highest. At other periods, maximum mesoplankton biomass was also recorded after dark (not more than 105 mg/cm$^3$, while in the day time it was reduced to 30-50 mg/cm$^3$. Mesoplankton biomass had average fluctuations from 70 to 100 mg/cm$^3$.

### B2-6007

## Short-period variability of oceanologic conditions in the vicinity of the Pulkovskaya seamount (Part II)

Vladimir B. Darnitskiy[1] and Maxim A. **Ishchenko**[2]

[1] Pacific Scientific Fisheries Research Center, P.O. Box 690950, 4 Per., Shevchenko St., Vladivostok, Russia
[2] V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, 43 Baltiyskaya St., Vladivostok, Primorsky Kray, 690041, Russia
E-mail: maksim@poi.dvo.ru; laitik@mail.ru

Calculation of geostrophic current velocities in a cross-sectional plane has allowed us to understand the evolution of the vortical field on the inter-daily and synoptic time scales above the Pulkovskaya Seamount and in its vicinity. During the first 10 days of the observations, the currents changed their directions four times at a periodicity of 1 to 3 days. The flow underwent a partial deformation every 24 h with the appearance (and disappearance) of several reverse streams, and subsequent alterations in horizontal and vertical flow structures. The geostrophic current velocities varied from several to 50-60 cm/sec, exhibiting from one to three maximum velocities in the case of diversely directed streams.

In February-March 1987, the cross-sections were repeated three more times in stages of 3 and 4 days in which an overall change in direction occurred during the first 3 days (the currents then had four diversely directed flows in the plane of the cross-section), with maximum velocities in both stages being quite high, 40 to 50 cm/sec. Then

(in another 4 days) the velocity abruptly slowed to 5-10 cm/sec, while the principal direction and structure of the flows remained unchanged. Apparently these changes were caused by the evolution of the vortical systems in the vicinity of the seamount, as was also observed in other regions (Darnitskiy, Zigelman, 1986).

The evolution of some other oceanological characteristics was also observed. In December 1986, the variations in temperature were mainly negligible over a 1500 m water column, within hundredths to tenths of a degree, although certain isotherms under the influence of internal waves underwent inter-daily vertical fluctuations of 80 to 120 m in amplitude in a 300 to 500 m thick layer. In the surface and subsurface layers, salinity variability was also negligible, but in intermediate horizons the layer of salinity minimum underwent vertical shifts within first dozens and first hundreds of meters, forming, at regular intervals, low salinity water lenses that grouped together at the seamount top. Judging from the vertical displacements of low salinity water nuclei, the water masses on intermediate horizons shifted vertically within 200 to 400 m, while the minimum salinity layer either totally covered the seamount top when the upwellings rose to the 400 m horizon, or was observed in the shape of lenses localized near the slopes at depths of 600 to 1200 m, when the waters descended.

**B2-6072**

## Modelling anchovy population in the Humboldt upwelling system

Olga **Hernandez**[1], Patrick Lehodey[1], Inna Senina[1], Arnaud Bertrand[2,3], Ramiro Castillo[3], Vincent Echevin[4] and Philippe Gaspar[1]

1 MEMMS (Marine Ecosystems Modelling and Monitoring by Satellites), CLS, Satellite Oceanography Division, 8-10 rue Hermes, Ramonville, 31520, France. E-mail: ohernandez@cls.fr
2 IRD, CRH, Avenue Jean Monnet, BP 171, 34203 Sète Cedex, France
3 Instituto del Mar del Perú, Esquina Gamarra y Gral. Valle s/n, Apartado 22, Callao, Lima, Peru
4 IRD, LOCEAN, Université Pierre et Marie Curie, Boite, 4 Place Jussieu, 75252 Paris, Cedex 05, France

The Humboldt Current system (HCS) off Peru and Chile is one of the most productive coastal upwelling systems in the world and the most productive system in terms of fish biomass (10% of the world fish catches). This system is submitted to high climatic stresses at different times scales, and is directly affected by "El Niño" and "La Niña" events. Anchovy and sardine have a relatively short life span and are fast growth species well adapted to this variability. They dominate the coastal HCS. Anchovy and sardine abundance were assumed to alternate in time on a decadal timescale. However, recent paleo-ecological studies suggest that this is not the case. Indeed, these studies show that the respective abundance of anchovy and sardine depends on different ocean-climatic factors.

Here we use an end-to-end model that integrates spatio-temporal and multi-population dynamics to test for possible mechanisms leading to changes in anchovy or sardine patterns of abundance. The model used is a spatial Eulerian ecosystem and population dynamics model (SEAPODYM) that has been developed to investigate the population dynamics of large pelagic fish (*e.g.* tuna) in relation to their bio-physical environment [Lehodey *et al.*, 2008]. We adapted the SEAPODYM model to small pelagic species and to a regional domain using the ROMS-PISCES physical–biogeochemical model as an input. In particular, thanks to an adaptation of the model, which was initially developed to use fishing data [Senina *et al.*, 2008], we incorporated information on fish abundance and distribution from acoustic data. Preliminary results of the model will be shown. On a medium term, this model aims at predicting future trends based on IPCC climatic change scenarios.

**B2-6088**

## Change in character of winter cyclonic activity over the Asian-Pacific region in 1996-2009 and its influence on a thermal regime of the Far East Seas

Svetlana Yu. **Glebova**

Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), 4 Shevchenko Alley, Vladivostok, Primorsky Kray, 690950, Russia. E-mail: glebova@tinro.ru

To analyze the characteristics of winter cyclonic activity in the Asian-Pacific region, seasonal charts of frequency and intensity of surface cyclones during 1996-2009 have been constructed. To define cyclonic frequency, whole region (there is a view the Asian-Pacific region) was broken into 2.5x2.5° squares and the total number of cyclones, passing through each square in January-March, was counted. To estimate the intensity, the Kunitsyn index of

cyclonicity was calculated as a square of the number of closed isobars outlining each cyclone. This index is proportional to the kinetic energy of each cyclone. Therefore, with its help it is possible to allocate energy active zones (EAZ). It is established that in 1996-2001 cyclones were more often displaced on meridional trajectories, and the area of the cyclones' maximum intensity (EAZ) was situated over the Bering Sea. In 2002-2009 zonal trajectories prevailed, and the EAZ was displaced towards the ocean and has come closer to the Okhotsk Sea. It is noted that with strengthening of the EAZ in winter: 1) In the Bering Sea, ice concentration in March increased and the water temperature decreased in spring; 2) in the Japan and Okhotsk seas and northern Pacific, the surface temperature rose, mainly in summer and autumn, but ice concentration decreased in March in the Okhotsk Sea.

On the whole, with intensification of cyclonic activity, the thermal regime in the Japan and Okhotsk seas becomes warmer, and in the Bering Sea is colder.

**B2-6132**

## Climate change and prospects of fisheries in the Barents Sea and adjacent Arctic seas

Boris **Prischepa**, Oleg Titov and Yuri Lepesevich

Knipovitch Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich St., Murmansk, 183038, Russia
E-mail: inter@pinro.ru

The last decade was, on the whole, characterized by steadily increasing air temperature over the Barents Sea and adjacent seas. Similar processes were observed in the hydrosphere. The global warming in the "ocean-atmosphere" system led to shrinking of the area covered with ice. Climate changes are already showing their effect on the biological resources of the Barents Sea and adjacent areas. Most evident changes are shown in the geographical distribution of marine species targeted by the fisheries and in the occurrence of new fish species traditionally living in warmer Atlantic waters. As a result of changing cycles of climatic processes in the last decade at the background of climate warming, the linkage between the Arctic and Atlantic oceanic systems became weaker, and the frontal zones in the Barents Sea became correspondingly less pronounced. In the light of this, it is suggested that climate warming could have a negative impact on the abundance of important commercial species such as cod and capelin, the habitats of which are closely related to the frontal zones. So, there is a need to move on from theory to practical aspects in studies of climate change implications. The program of investigations of fisheries resources in the Kara Sea was one of the steps to study the effects of global warming on the marine biological resources. This paper presents results from these studies.

**B2-6137**

## Response of krill to climate change in the California current: Temporal and spatial variations in population "hotspots"

Jennifer **Menkel**[1] and William T. Peterson[2]

[1] Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, 2030 S. Marine Science Dr., Newport, OR, 97365, USA. E-mail: jennifer.menkel@oregonstate.edu
[2] Northwest Fisheries Science Center, Hatfield Marine Science Center, 2030 S. Marine Science Dr., Newport, OR, 97365, USA

Using data from 42 oceanographic cruises spanning 10 years, we have identified regions along the Pacific coast of Oregon, USA that serve as population centers or geographical "hot spots" in euphausiid abundance for *Euphausia pacifica* and *Thysanoessa spinifera*. We hypothesize that these hot spots occur due to topography and circulation patterns that tend to concentrate and retain euphausiids in these areas. These retention zones also exhibit consistently strong upwelling and are less prone to perturbations and seasonal variation than other areas of the coastline. We will look at the climatic influences that help to generate strong recruitment years as well as influences that create weak cohorts. *Euphausia pacifica* has consistently strong years in most climatic conditions, being a more plastic and resilient species, whereas *Thysanoessa spinifera* has a stronger climatic response having better recruitment in cool ocean years of 2000 and 2002 and almost complete collapse in the warm ocean years of 1998 and 2005. We will explore the seasonal differences in the location of the population centers as well as inter-annual differences in biomass relative to ocean conditions.

**B2-6163**

## Spatial dynamics of small pelagic fish in the California Current system on the regime time-scale: Parallel processes in other species-ecosystems

Rubén **Rodríguez-Sánchez**, Héctor Villalobos and Sofía Ortega-García

Centro Interdisciplinario de Ciencias Marinas (CICIMAR-I.P.N.), Apartado Postal 592, La Paz, B.C.S., C.P. 23090, México
E-mail: rrodrig@ipn.mx

Some climate models predict that over the next decade natural climate variability may counteract the underlying anthropogenic warming trend in some ocean regions and may even cool slightly during this period. Possible scenarios of fluctuating climate change are distributional and composition changes of pelagic species. A previous large-scale, long-term analysis of the California Current system (CCS) suggests that climatic regime shifts in the northeast Pacific appear to have forced a changing population size associated with major geographical variations in the position of the center of distribution and bulk of the biomass of Pacific sardine *(Sardinops caeruleus*). This finding allows an explanation of i) the disappearance of the sardine population about 60 years ago from the northern part of the CCS, and also its return after the 1980s, and ii) the inverse relation of sardine and northern anchovy *(Engraulis mordax*) abundance. This differs from theories suggesting that environmental regime shifts lead to progressive population-level changes within assumed geostationary stocks. The question arising is if this natural pattern of variation is only recorded in the Pacific sardine. In this work 1) the large-scale, long-term (1931-1997) variability of tropical species in the CCS is included in the sardine-anchovy analysis, and 2) examples are shown for other pelagic and benthic species and communities from other ecosystems, where changes of abundance are also associated with changes in the center of distribution. We discuss the importance and implications of this spatial process in contrast to simple latitudinal extension shifts into the management of fisheries.

**B2-6186**

## Impacts of mesoscale variations of water masses on larval survival processes of pelagic fishes around the Kuroshio based on an eddy resolving ocean ecosystem model

Kosei **Komatsu**[1,2], Arisa Yamawaki[2], Daisuke Ambe[3], Takahiko Kameda[3], Takashi Setou[3] and Manabu Shimizu[3]

1 Graduate School of Frontier Sciences, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
E-mail: kosei@ori.u-tokyo.ac.jp
2 Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
3 National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa-ku, Yokohama, 236-8648, Japan

The Kuroshio, one of the strongest western boundary currents, is well known to severely fluctuate, interacting with energetic mesoscale eddies, and to play essentially important roles on characterizing marine ecosystems in the western North Pacific. Main spawning grounds of many commercially important pelagic fishes around Japan are formed around the frontal region of the Kuroshio, where eggs and larvae are transported along the Kuroshio through survival processes into their nursery grounds. Climate change seems to have an impact on the modification of water properties of the spawning and nursery grounds. However, its impact on the larval survival processes is unknown because of insufficient accumulation of observation data in the Kuroshio frontal region which has plenty of mesoscale eddies. To clarify the impacts of mesoscale variations of water masses on larval survival processes around the Kuroshio, we focus on Japanese jack mackerel (*Trachurus japonicus*), spawned mainly in the southern East China Sea and Japanese sardine (*Sardinops melanostictus*), spawned mainly in the nearshore region of Japan, and conducted particle transport experiments under realistic forcing in 1993-2006, using an eddy-resolving ocean ecosystem model composed of a lower trophic-level ecosystem model based on NEMURO and an OGCM assimilating satellite SSH/SST based on the adjoint ocean primitive equation model, C-HOPE developed by the Max-Planck-Institute. The numerical experiments indicated that the temperature and the zooplankton concentration, which pseudo-larvae experienced on their way from the spawning grounds to the nursery ones, change significantly year after year, affected by the fluctuation of the Kuroshio flow-path and the frontal eddies.

**B2-6198**

## Shifting species assemblages within the Northeast US Large Marine Ecosystem

Sean **Lucey** and Janet A. Nye

Ecosystem Assessment Program, Northeast Fisheries Science Center, National Marine Fisheries, 166 Water St., Woods Hole, MA, 02543, USA. E-mail: Sean.Lucey@NOAA.gov

The Northeast US Large Marine Ecosystem (NEUS LME) has experienced a variety of pressures due to fishing and climate. Differences in the reactions of marine species to these changes stemming from differential behavior and life histories have led to a variety of adaptations, which in turn alters the species assemblage of an area. The NEUS LME has traditionally been assessed using four eco-regions: Mid-Atlantic Bight, southern New England, Georges Bank, and Gulf of Maine. Although each eco-region has a distinct species assemblage, we found that those assemblages are shifting over time. The shift appears to be towards species that prefer warmer water, which creates an assemblage that more resembles the historic assemblage found in the adjacent eco-region to the south. We found that these shifts are occurring by a combination of fishing pressure and climate. Therefore, current reductions in fishing pressures may not be adequate to return the system to a more historic species assemblage.

**B2-6248**

## Reaction of northern hemisphere ecosystems to the climate events in the late 1980s: A comparison of regime shifts and teleconnection patterns

Jürgen **Alheit** and 12 co-authors

Leibniz Institute for Baltic Sea Research, Seestr. 15, Warnemünde, 18119, Germany. E-mail: juergen.alheit@io-warnemuende.de

Understanding the role of natural variability, occurring over a variety of time scales, is essential if we are to effectively manage marine ecosystems and their living resources in the wake of predicted global change. Evidence has been accumulated that climate variability can cause ecosystem regime shifts. These shifts can re-organize marine communities and trophodynamic relationships and induce changes in the mix of dominating species. Examples of regime shifts in the Atlantic (Baltic Sea, North Sea, NW Mediterranean) and Pacific (Japan/East Sea, Oyashio/Kuroshio System) will be described, based on long-term time series of atmospheric, hydrographic and ecosystem variables. The focus will be on the pelagic realm including phytoplankton, zooplankton and small pelagic fishes such as sardines, anchovies, sprat and saury. Often, aquatic ecosystems being separated by thousands of kilometers from each other react synchronously to the same climate signal, as did NE European shelf seas and lakes in association with the increase of the North Atlantic Oscillation index and NW Pacific ecosystems in association with the weakening of the East Asian winter monsoon, events all of which happened in the late 1980s. This Atlantic-Pacific teleconnection pattern seems to be mediated by the dynamics of the Arctic Oscillation and the Siberian High. The potential for forecasting these events will be discussed.

**B2-6271 (*Cancelled*)**

## Distribution variation of phytoplankton effect by typhoon winds in the South China Sea

Chun Li **Liu**[1] and Dan Ling Tang[2]

[1] Marine College, Shandong University at Weihai, 180 West Wenhua Rd., Weihai, 264209, PR China. E-mail: chunliliu@sdu.edu.cn
[2] Center of Remote Sensing on Marine Ecology/Environment, South China Sea Institute of Oceanology, Chinese Academy of Sciences, PR China

The present study analyzed the variation of phytoplankton/Chlorophyll-a (Chl-*a*) distribution in the South China Sea (SCS) for the period from August 2 to 15, 2009 using SeaWiFS-derived Chl-*a* data and other oceanographic data. The results show Chl-*a* concentration changed in 2 areas after the typhoon. A bloom along the typhoon track exhibited a Chl-a peak 5 d after the typhoon's passage. It was preceded by sea-surface cooling, mainly on the right side of the typhoon track, and sea-level decrease along the typhoon track 1 d post-typhoon. The bloom was due to nutrient increase from mixing and upwelling. By this mechanism, the typhoon winds can effect production of marine phytoplankton. The density of algal species increased after the typhoon and algal species were different before and after the typhoon winds.

**B2-6320**

## Environmental temperature impacts on the early survival process of larval Japanese sardine

Daisuke **Ambe**[1], Kosei Komatsu[2], Manabu Shimizu[1], Akira Okuno[3] and Akinori Takasuka[1]

[1] National Research Institute of Fisheries Science, Fisheries Research Agency, Yokohama, Kanagawa, 236-8648, Japan
E-mail: ambe@affrc.go.jp
[2] Graduate School of Frontier Sciences, The University of Tokyo, Nakano, Tokyo, 164-8639, Japan
[3] Japan Sea National Fisheries Research Institute, Fisheries Research Agency, Niigata, Niigata, 951-8121, Japan

Environmental transport and temperature impacts on the survival process of egg and early larval Japanese sardine *Sardinops melanostictus* in their low biomass period during 1993–2007were examined using in situ and satellite observational data. The first mode of spawning ground was located at the nearshore side of the Kuroshio axis south of Shikoku, and was at its peak in February. A 30-day virtual tracer experiment was carried out, in which the initial location of the tracers was set to the south of Shikoku. Satellite altimeter and drifter data showed that the tracers were passively transported by the sea-surface velocity field generally downstream of the Kuroshio soon after they were released. A few tracers crossed over the Kuroshio to offshore side. The average experiential temperatures of the tracers tended to decrease gradually with time. Both daily average and standard deviation of the experiential temperatures in February and March were continuously within the temperature range of their habitat. The yearly variation of the annual survival rate based on this temperature range showed rough agreement with the Recruitment Per Spawn (RPS) of Japanese sardine. These results suggest the high contribution of winter SST south of Shikoku to recruitment of Japanese sardine during its low biomass period. Based on the disagreement between this survival experiment and RPS, it was found that the spawning ground mode shifts eastward, associated with the interannual elevation of sea-surface temperature.

**B2-6373**

## Evidence of climate change in the northern California Current ecosystem and its impact on the distribution and community composition of zooplankton

Jay O. **Peterson**[1] and William T. Peterson[2]

[1] Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, Newport, OR, 97365, USA
E-mail: jay.peterson@oregonstate.edu
[2] NOAA-Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR, 97365, USA

Uncertainty exists in predictions of how climate change will impact aquatic ecosystems. For the California Current (USA), an eastern boundary current driven by upwelling, not only is a warming climate predicted to lead to increased water temperatures and stronger stratification, but also to more intense periods of upwelling. Physical and biological data from the northern California Current (NCC) ecosystem have been collected at various frequencies since 1969, with the most intense and consistent sampling occurring from 1996 - present. This long-term dataset encompasses phase changes in the Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), and El Niño Southern Oscillation (ENSO), providing information on how the NCC ecosystem may respond to climate shifts leading to warmer or colder ocean conditions and changes in upwelling strength and duration. We will address the long-term trends in physical variables (temperature, stratification, timing and strength of upwelling) and the associated changes in the abundance and species composition of meso-zooplankton. Over the last 40 years we have found several fundamental changes in the NCC, including an increase in the number of copepod species routinely found along the coast (0.11 species per year), an intensification of oxygen-depleted bottom waters on the shelf, and an increase in the depth from which water upwells. Variability within these trends correlates to the phase of the PDO and provides an indication of how the ecosystem responds to both warmer and colder ocean conditions.

**B2-6392**

## Long-term variations in the catch of sergestid shrimp in Suruga Bay induced by variations in the Kuroshio path and climate regime shifts

Takashige **Sugimoto** and Masato Niki

School of Marine Science and Technology, Tokai University, 3-20-1 Orido, Shimizu-ku, Shizuoka, Shizuoka Prefecture, 424-8610, Japan
E-mail: sugimoto@scc.u-tokai.ac.jp

Fisheries biologists think that the catch of sergestid shrimp becomes worse when associated with low water temperature or decreased thickness of the layer compared with the preferred water temperature for spawning and growth of larvae.

On the other hand, fishermen in Suruga Bay, in the southeastern coast of Japan, say that the large meandering path of the Kuroshio induces a remarkable drop in the catch, but that increased river discharge brings a better catch. To clarify this gap, we analyzed the historical data on the catch of sergestid shrimp, including their feeding environment, with ocean-climate conditions.

Results show that the relevant mechanisms of the inter-annual to inter-decadal scale variations in the catch of sergestid shrimp depend on a time scale as follows. (1) ENSO and the climate regime shift affect the variations in water temperature in summer and early autumn (spawning season) on a period of several years and several decades, respectively. Several years to decadal-scale variations in the water exchange during the spawning season happen in association with the large meandering path of the Kuroshio, which induces a remarkable decrease in recruitment. Variations in the mean SST around Japan in the last century show positive correlations with the catch of sergestid shrimp, as well as that of anchovy, on a time scale of 50-60 years.

# C1 Oral Presentations

**28 April, 9:05 (C1-6210), Invited**

## Adapting marine social-ecological systems to a world of change: Lessons from the GLOBEC experience

R. Ian **Perry**[1], Manuel Barange[2], Francisco E. Werner[3], Eileen Hofmann[4] and Rosemary Ommer[5]

[1] Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
E-mail: Ian.Perry@dfo-mpo.gc.ca
[2] GLOBEC International Project Office, Plymouth Marine Laboratory, Plymouth, PL1 3DH, UK
[3] Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ, 08901-8525, USA
[4] Center for Coastal Physical Oceanography, Old Dominion University, Crittenton Hall, Norfolk, VA, 23529, USA
[5] Institute for Coastal and Oceans Research (ICOR), University of Victoria, P.O. Box 1700 STN CSC, Victoria, BC, V8W 2Y2, Canada

Marine social-ecological systems, including biophysical and human components of marine ecosystems, are expected to be significantly impacted by the combined effects of globalisation, direct human activities, and climate change. Anticipated changes include changes in: distributions of marine species; phenology; recruitment success and abundances of marine populations; and disruptions and changes in the species composition of traditional marine communities. Each of these have impacts for marine-dependent human communities. What are the policy and management needs and implications for such coupled marine social-ecological systems in a world of increasing uncertainty and change? We present these issues in the context of findings and lessons learned during the >10 years of the international Global Ocean Ecosystem Dynamics (GLOBEC) program. We review key concepts and changes in understanding of how marine ecosystems work and respond to environmental and human forcing that evolved during the GLOBEC period. These include increased understanding of ecosystem structure and function, physical and anthropogenic forcings, and of how physical, biological, and human components interact with each other and with changing marine environments and ecosystems. We focus on policy needs and management implications of these findings, taking into account issues relating to policy development such as space and time scales, differences in national approaches, and dealing with (and making decisions under) uncertainty. The overarching issue is to understand the processes affecting, and to develop polices and to take decisions that strengthen, the capacities of coupled marine social-ecological systems to adapt to foreseen and unforeseen future global changes.

**28 April, 9:30 (C1-6310)**

## Postlarvae fishing, biodiversity and livelihoods under climate change: A case study on southwest coastal community in Bangladesh

Sujan **Saha**

Independent Researcher, C/O M. Chowdhury, Tings Vägen 21 TR 2, 145-56 Norsberg, Stockholm, 145-56, Sweden
E-mail: sujan407@yahoo.com

Prawn postlarvae fishing in coastal southwest of Bangladesh provides not only the livelihoods for many marginalized women and children, but it is one of the major exports earning for Bangladesh. However those come at a cost for the environment and climate change is bringing new challenges on the sector and on marine ecosystems in Bangladesh.

This paper teases out how climate change impacts on prawn postlarvae and on the fishing community dependent on postlarvae in southwest of Bangladesh. The paper finds climate change related causes, like habitat destruction and salinity intrusion, have drastic effects on prawn postlarvae. The negative consequences of climate change like storm surges make the fishing community destitute and force them to abandon their sole livelihood option. The paper argues for a community-based system to increase the resilience of the livelihoods of marginalized people and to save the environment in the era of climate change. A community-based governance and management structure could allow for fishing activity without jeopardizing the marine ecosystem, while government's initiatives such as spatial and seasonal ban on fishing, and afforestation of mangrove tress would help marine ecosystems in coping with negative consequences of climate change.

**28 April, 9:45 (C1-6340)**

## Modeling the spatial distribution of coastal fisheries of the Baltic Sea using Geographic Information Systems

Eva **Papaioannou**[1], Athanasios Vafeidis[1], Jörn O. Schmidt[2] and Martin F. Quaas[2]

[1] Sea-Level Rise and Coasts at Risk Research Group, Cluster of Excellence 'The Future Ocean', Institute of Geography, Christian Albrechts University of Kiel, Ludewig-Meyn Str. 14, 24098, Kiel, Germany. E-mail: papaioannou@geographie.uni-kiel.de

[2] Fisheries and Overfishing Research Group, Cluster of Excellence 'The Future Ocean', Department of Economics, Christian Albrechts University of Kiel, Wilhelm-Seelig-Platz 1, 24118, Kiel, Germany

The safeguarding and sustainability of coastal fisheries constitute central priorities in the process of current and ongoing institutional and legislative fisheries' reforms, on both an international and a regional level. In the Baltic Sea, coastal fish communities have long been recognized as important components of the marine ecosystem, while the fishery is an important income and employment generating sector, particularly for fishery-dependent coastal communities.

This study aims to assess how the spatial distribution of the Baltic coastal fishing fleet and its economic benefits are affected by ecological and economic factors (such as habitat characteristics and fishing technology), using Geographic Information Systems. Assuming that the coastal fleet can be defined in terms of gear type, vessel size, and relative distance travelled to fishing grounds, a time-series database of coastal vessels is created, allocating vessels per country and port. Furthermore, catch data on important coastal fish are analysed at the level of ICES Subdivisions (*i.e.* Subdivisions 22 to 32 and IIIa); additional data are used, where available, for refining the resolution of catch data (logbook data, results from coastal fish surveys). Then, the data are employed for analyzing the spatial distribution of coastal vessels and their catch. Finally, preliminary results generated within the context of commonly employed climate-change scenarios, enable a first-order assessment of the future distribution of the coastal fleet and its catches.

**28 April, 10:00 (C1-6174)**

## Satellite observation on the cold water intrusion related to the exceptional fishery disaster during the ENSO events in the Taiwan Strait

Ming-An **Lee**[1,2], Kuo-Wei Lan[1], Kuo-Ten Lee[1] and Yi Chang[1]

[1] Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, Pei-Ning Rd., Keelung, 20224, Taiwan, ROC. E-mail: malee@mail.ntou.edu.tw

[2] Remote Sensing Laboratory of Taiwan Ocean Research Institute, Keelung, 20224, Taiwan, ROC

From the long-term (1995-2008) observation of wintertime sea surface temperature (SST) fields of satellite-derived data, it is interesting that an exceptional cold water intrusion into the southern Taiwan Strait happened in February 2008. It is found that in January to February of 2008, the SST decreased from 20.2 to 12.6ºC (a drop about 7.6ºC) which resulted in great damage to marine ecology and fisheries economics. This rare low SST event caused the death of more than 130 tons of resident, coral reef and cage aquaculture fishes. Comparing the catch of fish in 2008 with the average of 1998-2007, we found a 50-80% decrease in the catch of pole and line boats, gill nets and longline fisheries but a 193% increase in the catch of the set net fishery.

It is found that SST was cooler in the La Niña winters (1996, 2000, 2008) than in the El Niño winters (1998, 2003, 2007). It is suggested that in the winter of 2008, the strong and continuous northeasterly wind caused by La Niña event probably drove the cold current more southward to penetrate into the southern Taiwan Strait. Therefore, the exceptional intrusion of cold water may decrease the feeding activity of warm water and resident species of fishes, which were killed by low body temperature and loss of energy as a result of reducing nutrient. The intrusion of cold current may also have brought some schools of cold water and migratory species from East China Sea to southern Taiwan Strait.

**28 April, 10:15 (C1-6201)**

## High latitude climate variability and its implications for fish resources as revealed by fossil otoliths of cod (*Gadus morhua*)

Audrey J. **Geffen**[1], Arild Folkvord[1], Hans Høie[1,4], Anne Karin Hufthammer[2], Carin Andersson[3], Kjell Nedreaas[4] and Ulysses S. Ninemann[3,5] (presented by Mei-Yu Chang)

1 Department of Biology, P.O. Box 7803, University of Bergen, N-5020, Norway. E-mail: Audrey.Geffen@bio.uib.no
2 Natural History Collections, University of Bergen, Muséplass 3, Bergen, N-5020, Norway
3 Bjerknes Centre for Climate Research, Allégaten 55, Bergen, N-5007, Norway
4 Institute for Marine Research, Bergen, P.O. Box 1870, Nordnes Bergen, N-5817, Norway
5 Department of Earth Science, University of Bergen, Allégaten 41, Bergen, N-5007, Norway

While it is important to understand climate changes which have occurred over the geological scale, it is those changes over historical time that have most immediate impact on us and our relationship to fisheries resources. By understanding the pattern of natural climate change over the course of human history we may be better able to assess the impact of future change, man-made or natural. Human settlements in northern Norway have relied on the availability of cod for over a thousand years. Present day population structure reveals the occurrence of local resident cod populations as well as the migratory Northeast Arctic cod which probably represented an important seasonal resource. We analyzed cod otoliths from archaeological sites in northern Norway to reconstruct the temperature regime experienced by fish and determined age, growth, and stock identity. These otoliths were compared with modern samples collected during routine fish assessment surveys during the last decade. Seasonal temperature cycles reconstructed from oxygen isotope (delta$^{18}$O) transects revealed seasonal variations consistent with the expected annual temperature range. Reconstructions of the size, age and growth characteristics of individual fish based on otolith growth increments were within the range seen in modern cod. The majority of the excavated otoliths were characteristic of Northeast Arctic cod. This implies that the human settlements have a long history, even prior to the industrial fishery, of taking advantage of seasonally available fish resources in Northern Norway. Changes in the distribution of fish populations/stocks can leave their mark in the archaeological remains of coastal settlements.

**28 April, 10:30 (C1-6233)**

## Reconstruction of bottom phytocenoses on the coast of Primorye caused by climate change

Tatiana **Krupnova**, Yury I. Zuenko, Vladimir Matveev, Irina Tsypysheva and Vladimir Pavlyuchkov

Pacific Research Institute of Fisheries and Oceanography (TINRO-Centre), 4 Shevchenko Alley, Vladivostok, Primorsky Kray, 690950, Russia. E-mail: krupnova@tinro.ru

The kelp *Laminaria japonica* dominates in phytocenoses on the Russian coast of the Japan Sea, and it occupied not long ago almost all available substrata from the shoreline to the depth 20 m. However, the stock of this alga decreased more than tenfold in the late 1990s and its distribution shrank simultaneously. These changes undermined the catch of this species and the forage base of other valuable commercial species such as sea urchin. As a result, coastal enterprises dependent on kelp catching and processing have material losses and partially collapsed. The relationship of laminaria reproduction with the intensity of the cold Primorye Current is shown. Recently the reproduction has generally been unsuccessful under conditions of warm surface water of subtropic origin. This is advected to the coastal zone in autumn and causes the formation of weak generations of laminaria and alteration of phytocenoses. Highly-productive fields of laminaria are replaced by low-productive coralline algae. The mechanism of this flow formation is discussed. A regression model of the laminaria stock formation that depends on the duration of the period with optimal water temperature has been developed to forecast the stock with a lead time of 2 years. Recommendations for developing sustainable coastal economics on the base of marine farms for joint cultivation of laminaria and sea urchins in natural environments are discussed.

**28 April, 11:05 (C1-6400), Invited**

## Evolution in an instant: Adaptation and resilience to climate change in fisheries

Kevern L. Cochrane, Tarub **Bahri**, Cassandra de Young and Doris Soto

FAO MedSudMed Project, Via Luigi Vaccara, 61, Mazara del Vallo, TP, 91026, Italy. E-mail: Tarub.Bahri@fao.org

The 4th Assessment Report of the IPCC provides best estimates of an increase in temperature of between 1.8 and 4.0°C in the 100 years up to 2090/2099 with sea level rises of between 18 and 59 centimetres. Change anywhere within these ranges will have profound impacts on coastal and marine ecosystems and on those dependent on them for their livelihoods. This will include the approximately 500 million directly and indirectly dependent on fisheries, the vast majority of whom are poor.

Even in the absence of climate change, the future of the fisheries sector in many regions has been at risk for several decades from over-fishing, pollution, coastal zone development and other anthropogenic effects. In response to these threats a number of key global instruments have been developed and are being implemented, including for example the UN Law of the Sea and the FAO Code of Conduct for Responsible Fisheries. This paper will summarise the key ecological and social threats, and some opportunities, from climate change and describe the relevance of the existing instruments to building resilience and facilitating adaptability amongst coastal fishery communities. It will also discuss the implications of the additional layer of uncertainty introduced into managing for sustainability by climate change. With reference to resilience theory, this will include consideration of the options for maintaining the functionality of coastal fishery social-ecological systems in the face of the substantial perturbations which are forecast for some regions under climate change either as slow or fast onset changes.

**28 April, 11:30 (C1-6124)**

## Socio-economic impacts of climate change on coastal communities: The case of the north coast of Java small-pelagic fisheries

Akhmad **Fauzi**[1], Subandono Diposaptono[2] and Suzy Anna[3]

1 Department of Resource and Environmental Economics, Bogor Agricultural University. Jl. Kamper, Wing 5, Level 5, Kampus IPB Darmaga, Bogor, 16680, Indonesia. E-mail: fauziakhmad@gmail.com
2 Ministry of Fisheries and Marine Affair, Republic of Indonesia, Jl. Medan Merdeka Timur, Jakarta, Indonesia
3 Faculty of Fisheries, Padjadjaran University, Kampus UNPAD, Jatinangor, Bandung. Indonesia

Climate change, along with other anthropogenic factors, has been perceived to be playing role in the declining of fisheries production in the north coast of Java. These factors not only generate uncertainties in the livelihood of small-scale fishers but also affect coastal community severely both socially and economically. The catch of small pelagic has been reported to be declining during the last ten years. Income and livelihood of small-scale fisheries have also been severely affected leading to poverty in coastal communities. This paper discusses how climate change has altered fisheries activities of artisanal fishers and how coastal communities respond to such uncertainties using livelihood strategies. These include temporal and seasonal migration, income diversification, developing work sharing, investing in social capital, and exploring non-fisheries resources. This paper also explores the impact of these livelihood strategies on the resources and communities.

**28 April, 11:45 (C1-6351)**

## Impacts of changing weather patterns on the efficiency of South Africa's purse-seine fishery

Janet C. **Coetzee**, Kobus Agenbag, Carl van der Lingen, Larry Hutchings, Jan van der Westhuizen, Awie Badenhorst and Mike Copeland

Marine and Coastal Management, Department of Environmental Affairs, Private Bag X2, Rogge Bay, 8012, South Africa
E-mail: Jcoetzee@deat.gov.za

Climate change is likely to impact the South African pelagic fishing industry in two ways; through altered functioning of the marine ecosystem and changes in local weather patterns. A fishery for anchovy and sardine has been in operation on the West Coast of South Africa since the 1940s. This fishery has already faced challenges related to stock fluctuations and geographical shifts in the distribution of target species and responded well

through altered fishing strategies. Recent changes in local weather patterns and the introduction of environmental regulations are impacting negatively on the ability of this industry to catch and process their allocated anchovy quotas and could potentially threaten the viability of the low-profit fishmeal-reduction component of the industry. In the past four years, this industry has caught only 40% on average of its anchovy TAC mainly because of the systematic intensification since 2003 of north-westerly winds during the winter fishing season. The anchovy fishery has been hardest hit because it relies on purse-seine vessels that cannot fish during adverse weather and because processing of anchovy into fishmeal increases air pollution and water effluent which are regulated. It remains unclear whether the recent enhanced winter storms are a consequence of climate change or decadal variation, but various predicted climate change scenarios suggest that the intensity of winter storms may be enhanced, resulting in stronger winds and rougher seas during the main fishing season. This fishing industry will again be forced to adapt its strategy to cope with these altered conditions.

**28 April, 12:00 (C1-6166)**

## Detecting decadal changes in marine environmental characteristics and fishery resources in Korean waters

Jong Hee **Lee**[1,2], Jae Bong Lee[1], Young Min Choi[1] and Chang Ik Zhang[2]

[1] National Fisheries Research and Development Institute, Busan, 619-705, R Korea. E-mail: leejb@nfrdi.go.kr
[2] Pukyong National University, Busan, 608-737, R Korea

Changes in temperature and salinity were analyzed using serial station data of NFRDI (National Fisheries Research and Development Institute) from 1962 to 2007, by dividing Korean waters into eight areas, of which are two in the Japan/East Sea, three in the Yellow Sea, and three in the East China Sea, namely E1, E2, W1, W2, W3, S1, S2, and S3, respectively. RSI (regime shift indices) were calculated for the eight areas to examine the patterns of change among the areas. All the eight areas showed decadal patterns of change in the years of 1976-77, 1988-89 and 1998-99, which are widely known as years of climatic regime shifts (CRS) in the North Pacific. The changes in the index for 1988-89 and 1998-99 were stronger than for 1976-77. The changing pattern for 1976-77 was only shown in the Japan/East Sea at E1 and E2 stations, and the RSI was weak in 1976-77 at S3 which is connected with E2. Although changes in RSI were commonly detected in 2006-07 in all Korean waters, the magnitude was not statistically significant. The 1976-77 CRS was manifested by a replacement in biomass and catch of major exploited fisheries resources, such as Pacific saury, sardine and filefish in the Japan/East Sea. In addition, fishery production in the waters showed decadal trends with an increase in 1976, a decrease in 1986, and an increase again since late 1990s. In 1960s and 1990s common squid was dominant, but in 70s and 80s it was replaced by walleye pollock. Other CRS events also changed the structure and function of the marine ecosystem, and the biomass and production of fisheries resources in Korean waters.

**28 April, 12:15 (C1-6236)**

## The potential use of a Gadget model to predict stock responses to climate change in combination with Bayesian networks: The case of the Bay of Biscay anchovy

Eider **Andonegi**[1], Jose Antonio Fernandes[2], Iñaki Quincoces[1], Xabier Irigoien[2], Daniel Howell[3] and Gunnar Stefansson[4]

[1] AZTI-Tecnalia, Txatxarramendi Ugartea z/g, Sukarrieta (Bizkaia), 48935, Spain. E-mail: eandonegi@azti.es
[2] AZTI-Tecnalia, Herrera Kaia – Portu Aldea z/g, 20110 Pasaia (Gipuzkoa), Spain
[3] Institute of Marine Research, P.O. Box 1870, Bergen, N-5817, Norway
[4] Department of Mathematics, University of Iceland and Marine Research Institute, Skúlagata 4, P.O. Box 1390, 121 Reykjavik, Iceland

European anchovy (*Engraulis encrasicolus,* Linnaeus, 1758*)* is a short-lived pelagic species that is distributed along the Atlantic European waters, with the Bay of Biscay being one of the main nuclei of concentration of individuals. The Bay of Biscay population has historically been the target species for a very important fishery, not only for economic reasons but also due to cultural roots of the surrounding countries. Landings have fluctuated over time, reaching a maximum during the 60's (around 83000t) and a minimum in 2004 (less than 10000t), just before the closure of the fishery that took place in July 2005 due to the collapse of the stock. Being a short-lived species, the state of the stock is largely determined by incoming recruitment. This recruitment is highly variable and depends on a variety of factors such as the size of the spawning stock and environmental conditions in the area.

In this study a Gadget like model has been used to analyze the status of the Bay of Biscay anchovy population and to simulate future scenarios based on estimated recruitment levels. Recruitment has been estimated using supervised classification techniques, tested by the machine learning community, and considers climatic indices as potential forecasting factors. Stock-recruitment relationships have not been considered in this work, since they have been classified as poor predictors of recruitment in previous studies and they are discarded by the supervised classification techniques.

**28 April, 12:30 (C1-6197)**

## Shifts in species abundance of sardine fisheries in southern Philippines: Early signs of vulnerability to climate change?

Asuncion **De Guzman**[1], Cesaria Jimenez[1], Angelo Macario[2], Juliet Madula[1] and Jayrald Santamnina[1]

[1] Mindanao State University at Naawan, Naawan, Misamis Oriental, 9023, Philippines. E-mail: sony_deguzman@yahoo.com
[2] Dipolog School of Fisheries, Bgy. Olingan, Dipolog City, Philippines

A newly implemented research program called ICE CREAM (*Integrated Coastal Enhancement: Coastal Research, Evaluation and Adaptive Management*) funded by the Philippine government is evaluating the impacts of climate change on coastal ecosystems, fisheries vulnerability, and local adaptive capacity. A component of this program is looking into the potential effect of climate changes on the production of important fish resources and on the livelihood of small fishers. The Indian oil sardine *Sardinella longiceps* forms a large part of the small pelagics production of nearshore fisheries in many bays of Mindanao in southern Philippines. This sardine is associated with high productivity areas such as upwelling zones or highly eutrophic systems driven by nutrient load from land, a possible proxy to changing climate. One of three major upwelling systems in the Philippines is found off Dipolog City and Sindangan Bay on the northwestern part of Mindanao Sea. High annual production of sardine in this area has motivated the rapid growth of the postharvest industry. Recently, however, fishers observed the failure of once-abundant sardine stocks to enter Sindangan Bay for almost two years. Initial results of the project show that sardine production in Sindangan Bay drastically dropped this year, forcing postharvest facilities to suspend production. In contrast, catches of *S. longiceps* exhibited a phenomenal rise in Butuan Bay on the northeastern side of Mindanao Sea. Since overfishing is common in Philippine coastal fisheries, the possible influence of climate-related factors on sardine production in the two bays is being investigated.

**28 April, 12:45 (C1-6304)**

## Challenge and opportunity of climate change: Case studies in Vietnamese coastal communities

Nhung T.H. Nguyen[1] and Hien T.H. **Than**[2]

[1] Royal Holloway, University of London, Egham, Surrey, TW20 0EX, UK. Email: nguyen.t.h.nhung@gmail.com
[2] Centre for Marine Conservation and Community Development, Hanoi, Vietnam. E-mail: tthien@mcdvietnam.org

Like many other coastal and island countries, climate change is leaving great impacts on Vietnam's coasts. Vietnam is one of the five most vulnerable countries to climate change and sea-level rise in Asia, according to a World Bank assessment (Dasgupta *et al.*, 2007). Overfishing, mangrove degradation, pollution, and extensive urban growth have accelerated climate change impacts on coastal communities and their livelihoods. Coping strategies are mainly government initiatives from the perspectives of advancing science and policies towards climate change. However, coastal communities in Vietnam, who have experienced many changes and have developed traditional knowledge of the natural environment, are rarely considered in studies of climate variability and responses to climate change. Despite the domination of centralized policies, many fisheries communities in Vietnam have established and exercised their own organizations and regulations to successfully manage coastal resources and to cope with changes in the climatic and political environment. This paper assesses local systems of coastal resource management and patterns of local responses, such as livelihood adaptation, resilience, migration, and the establishment of local institutions. The paper documents historical changes in the coastal environment, the impacts of these on coastal communities, and associated livelihood strategies in these periods using case studies of coastal wetlands in the Red River Delta of Vietnam. The paper makes recommendations on the capacity and the involvement of communities and local stakeholders in coastal resource governance towards climate change adaptation and mitigation.

# C1 Posters

**C1-5998**

## Assessment of adaptation responses of coastal communities in the Philippines to the impacts of climate change

Maria Rebecca A. **Campos**

Southeast Asian Regional Center for Graduate Study and Research in Agriculture, 10996 Campos Compound, Faculty Village, College, Laguna, 4031, Philippines. E-mail: cmaribec@yahoo.com

More than half a million small fishers in the Philippines have been availing of loans from Quedancor, the credit arm of the Department of Agriculture. The financing scheme has been quite successful with repayment rate at 95%. However, the occurrence of natural calamities such as typhoons; as well as pests and diseases has affected the productivity of fisheries, thus, hindering fishers from paying and renewing their loans. Failure to access credit could disable them to continue venturing on fishing activities and could eventually jeopardize the welfare of their entire household. The inability of creditors to pay their loans and meet their obligations also impair, to a large extent, the financial operation and viability of the lending institutions. This study analyzes the natural risks and risk management practices of these fishers. It recommends mitigation mechanisms to minimize the impact of natural calamities. Moreover, it suggests a bridge financing scheme that can be an effective and efficient instrument to enable fishers to carry on their livelihood activities and support their families' basic needs and slowly recover from their losses.

**C1-6040**

## Status of short-spined sea urchin (*Strongylocentrotus intermedius*) colonies and kelp (*Laminaria japonica*) thicket along southwestern Sakhalin coast

Dmitry A. **Galanin**, V.A. Sergeenko and A.R. Repnikova

Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO), 196 Komsomolskaya St., Yuzhno-Sakhalinsk, 693023, Russia
E-mail: dmitry.galanin@yahoo.com

In recent years the status of commercial algae and sea urchins along southwestern Sakhalin coast is not stable. This is rather visible in traditional fishery areas of *Laminaria japonica* and *Strongylocentrotus intermedius*. The distribution area for *Laminaria japonica* has reduced that causes decline in total and commercial biomasses. The mean sizes of short-spine sea urchin become smaller that causes decline in their total and commercial biomasses as well.

We study dynamics of size characteristics of the sea urchins and *Laminaria japonica* during a long period and compare it with environmental conditions. This allows us to reveal significance of some factors in colonies existence. Thus, for instance, a temperature factor is the most significant for major physiological processes, including hydrobionts spawning. A definite temperature regime stimulates sea urchins for spawning and *Laminaria* for spore-bearing. Such regime affects the hydrobionts growth (acceleration or delay). Surely, none of the environmental factors functions alone. Their combination always determines a status of hydrobiont stocks. Accumulation and generalization of such data allow us to predict a status of their resources for future.

**C1-6116**

## Impacts of ENSO and IOD on summer monsoon rainfall and oil sardine fishery along the west coast of India

K.J. Thara[1], R. **Sajeev**[1] and T. Pankajakshan[2]

[1] Department of Physical Oceanography, School of Marine Sciences, Cochin University of Science and Technology, Kochi, Kerala, 682 022, India. E-mail: rsajeev@yahoo.com
[2] Embassy of India, Tokyo, Japan

Indian summer monsoon (June-September) has a large interannual variability over temporal as well as spatial scales. In recent decades, the number of extreme rainfall events increased a lot and the inverse relationship between ENSO and Indian summer monsoon has broken down. IOD plays a major role and its correlation with rainfall is high. During the last few decades, the IOD and ENSO have complementarily affected the Indian summer monsoon rainfall. In this study the relative impacts of the IOD and ENSO events on the summer monsoon rainfall of west coast of India during the period 1991-2008 have been examined. The spatial distribution of partial correlations between Dipole Mode Index (DMI) and rainfall indicates that there exists a significant impact of IOD on rainfall along the southwest coastal regions of India. There was a strong negative correlation with positive Nino 3.4 Index (El Niño) along entire coastal regions during 2000-2008. But during 1991-1999, a period with strong and continuous IOD-ENSO events the correlation was positive. This substantiates the impact of IOD on rainfall. Oil sardine landings showed a significant negative correlation with DMI and also with summer monsoon rainfall. The summer monsoon rainfall affects the oil sardine fishery of southwest coast of India to a large extent.

**C1-6146**

## Loss of mangrove wetlands and implications for climate change, fisheries and food security in Lagos coastal lagoons shorelines (West Africa)

Julius I. **Agboola**

Department of Fisheries, Lagos State University, P.M.B 0001 LASU, Ojo, Lagos, Nigeria. E-mail: jb_agboola@yahoo.com

The future of coastal lagoons shorelines in Africa especially in Lagos, Nigeria and its people is highly related to the future of its mangrove wetlands. However, global trend indicates that wetlands are degrading at an alarming rate, to which those in Nigeria (West Africa) are no exception. This appears to be threatened by the expansion of wetland reclamation for urban housing developments, which have led to wetland loss, tilapia fisheries collapse, enhanced eutrophication of the lake, loss of food security for the impoverished population, and a measurable contribution to global warming. This papers analyses trends (past to present) and implications, and argues for better management strategies through "strategic partnership" and "integrated management" for sustainable management of aquatic resources in the face of global environmental change uncertainties. It hoped that this will achieve a better understanding of risks and opportunities of trade-offs in aquatic ecosystem services.

**C1-6147**

## The effect of climate change upon the inshore fisheries of the United Kingdom

Mark **Prime**, Ralf Bublitz, Bob Houghton and Magnus Johnson

Centre for Environmental and Marine Sciences, University of Hull, Scarborough Campus, Filey Rd., Scarborough, YO11 3AZ, UK
E-mail: m.prime@2008.hull.ac.uk

The UK coast is very diverse in the species fished, the habitats present and the methods used to fish. For over 100 years, 12 independent Sea Fisheries Committees (SFC) of England and Wales have had responsibility for near-shore and small scale fisheries management within their own districts. This has resulted in each SFC being specialised towards locally important fisheries. Consequently data has been collected without reference to neighbouring districts, offshore activities or the wider national picture, mostly for the purposes of fisheries management in the short term rather than developing a long term ecological understanding. Analysis of SFC data

will demonstrate the changes in the UK fisheries that are products of climate change processes. Utilising SFC data we are able to highlight changes in commercial species abundance, distribution and composition. For example, sea bass (*Dicentrarchus labrax*) a species that was previously associated with South Western fisheries only has seen a marked increase in its range across the UK. Ultimately we hope to develop a intuitive tool that enables locally collected data to be interrogated for nationally relevant questions, that feeds into our understanding of the impact climate change is having upon distributions of near-shore species and inshore fishing activity.

**C1-6242**

## Trends of coastal fisheries in Iwate Prefecture, Pacific coast of northern Japan, with relation to the long-term oceanographic fluctuations

Tomoaki **Goto**

Iwate Fisheries Technology Center, 3-75-3 Heita, Kamaishi, Iwate, 026-0001, Japan. E-mail: t-gotou@pref.iwate.jp

A large number of various capture fisheries with small-scale fishing boats have been operated in the coastal waters off Iwate, Pacific coast of northern Japan, where form the Oyashio-Kuroshio mixing zone. In the present study, relationship between fisheries and long-term temperature fluctuations was evaluated on the basis of annual catch statistics and hydrographic observation data collected by Iwate Fisheries Technology Center. Two different trends were found between set-nets and other fisheries. Total catch levels by set-nets have been maintained relatively high depending upon the decadal changes of dominant fish due to regime shifts and local oceanographic shifts as: *Seriola quinqueradiata, Scomber* spp. and *Todarodes pacificus* in the 1960s, *Sardinops melanostictus* in the 1980s, *Oncorhynchus keta* in the 1990s, and *O. keta, Scomber* spp., *S. quinqueradiata* and *T. pacificus* in the 2000s. On the other hand, total catches by other small-scale fisheries, in which the target fish are limited by each boat due to the selectivity of fishing gear, have been greatly decreased since the 1990s. In these fisheries, a lot of fish, *e.g. T. pacificus*, *Scomber* spp., *Ammodytes personatus, Cololabis saira*, flounders and sharks, were captured by various fishing gears as long-lines, squid jigging or lift nets during 1960–1970. Since the 1980s, the catch diversity has been decreased due to the concentration of the dominant fish in *O. keta, C. saira* and *Euphausia pacifica* by means of not only oceanographic changes but also the decrease of fishing efforts depending upon the social factors.

**C1-6257**

## Mitochondrial and microsatellite DNA structure of the small yellow croaker, *Larimichthys polyactis* (Pisces: Sciaenidae) in the Yellow and East China Seas

Jin Koo **Kim**[1], Gi-Sik Min[2], Moon-Geun Yoon[3] and Yeonghye Kim[4]

1 Department of Marine Biology, Pukyong National University, Busan, 608-737, R Korea. E-mail: taengko@hanmail.net
2 Department of Biological Sciences, Inha University, Incheon, 402-751, R Korea
3 Institute of Marine Living Modified Organisms, Pukyong National University, Busan, 607-737, R Korea
4 National Fisheries Research and Development Institute, Busan, 619-705, R Korea

Genetic variation was surveyed at the mitochondrial (mt) DNA control region (766bp) and four microsatellite (ms) DNA loci to test for the presence of genetic stock structure in the small yellow croaker, *Larimichthys polyactis* in the Yellow and East China Seas. Based on mtDNA control region sequence data, individuals of the small yellow croaker could not be distinguished on the basis of its location, as demonstrated using the neighbor-joining (NJ) method and the minimum spanning network (MSN). AMOVA revealed no significant differences among collections of the small yellow croaker taken from the four locations (each two locations in Korea and China). Neutrality tests and a mismatch distribution analysis indicated that this species has recently expanded. Based on msDNA marker variation, estimate of expected ($H_E$) heterozygosity for four microsatellites in each population ranged from 0.776 to 0.947. The pairwise $F_{ST}$ values ranged between 0.007 and 0.037. The results obtained thus indicated congruence of both mtDNA and msDNA markers in the genetic differentiation, which was no significant signal of differentiation between Korean and Chinese populations of the small yellow croaker. Our findings suggest that the small yellow croaker either has a high migration capability that enables it to overcome the effects of genetic drift, or that this species expanded relatively recently and has not yet had sufficient time to differentiate.

**C1-6265**

## Contesting views or collaborative opportunity? Risk perception, science and fisheries management, Tasmania, Australia

Melissa **Nursey-Bray**[1], Gretta Pecl[2], Stewart Frusher[2], Caleb Gardner[2], Marcus Haward[3], Alistair J. Hobday[4], Sarah Jennings[5], André E. Punt[6], Hilary Revill[7] and Ingrid van Putten[4]

1 National Centre for Marine Conservation and Resource Sustainability, Australian Maritime College – a specialist Institute of the University of Tasmania, Locked Bag 1370, Launceston, Tasmania, 7250, Australia. E-mail: m.nursey-bray@amc.edu.au
2 Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Private Bag 49, Hobart, Tasmania, 7001, Australia
3 School of Government and Antarctic Climate and Ecosystems CRC, University of Tasmania, Private Bag 22, Hobart, Tasmania, 7001, Australia
4 CSIRO Marine and Atmospheric Research, P.O. Box 1583, Hobart, Tasmania, 7001, Australia
5 School of Economics and Finance, University of Tasmania, Private Bag 85, Hobart, Tasmania, 7001, Australia
6 Marine Population and Management Group, School of Aquatic and Fishery Sciences, University of Washington, P.O. Box 355020, Seattle, WA, 98195-5020, USA
7 Wild Fisheries Management Branch, Department of Primary Industries and Water, P.O. Box 44, Hobart, Tasmania, 7001, Australia

World fisheries, already vulnerable, are under increasing pressure from the impacts of climate change. This paper addresses this challenge. Using the Tasmanian rock lobster industry as a case study, we consider the efficacy of risk perception as a tool to inform science and management in relation to development of adaptation strategies for fisheries in a climate change context.

Specifically, we report on the results of a risk perception exercise, conducted with rock lobster fishers in Tasmania, in order to gain insights into fisher understanding of the impacts of climate change. This study, conducted as part of an inter-disciplinary vulnerability assessment of the Tasmanian rock lobster revealed high scepticism within the industry in relation to perceptions of climate change *per se*. Nonetheless, research results produced a high degree of anecdotal evidence relating to observed changes to the environment that were correlative with predicted climate change impacts for the species. In a follow up workshop that utilised various scientific climate scenarios, fishers also identified a range of adaptation strategies for the industry.

Research shows that public risk perceptions often drive policy as much as scientific assessments. This paper reflects on our collective experience of participating in an interdisciplinary vulnerability assessment. In this context, we argue that in fact it is when the results of risk perception work are combined with scientific and other assessments, that the insights gained can play a catalytic role in generating awareness about as well as inform policy and fisher, responses to climate change.

**C1-6284**

## Forecasting practice on the common squid (*Todarodes pacificus*) population responding climate/oceanographic changes

Suam **Kim**[1], Sangwook Yeh[2], Chung-Il Lee[3], Sukyung Kang[4], Hyunwoo Kang[2], Jin-Hee Yoon[2], Jung Jin Kim[1] and Sinjae Yoo[2]

1 Department of Marine Biology, Pukyong National University, 599-1 Daeyeon3-dong, Nam-gu, Busan, 608-737, R Korea
E-mail: suamkim@pknu.ac.kr
2 Korea Ocean Research and Development Institute, Ansan P.O. Box 29, 425-600, Seoul, R Korea
3 Kangnung-Wonju National University, 120 Gangneung Daehangno, Gangwon-do, 210-702, R Korea
4 National Fisheries Research and Development Institute, 152-1 Haean-ro, Gijang-gun, Busan, 619-705, R Korea

The common squid, *Todarodes pacificus*, is the most abundant fishery resource in Korean waters, and it has been known that its biomass generally fluctuates in accordance with the changes in ocean temperature. However, wind velocity and mixed layer depth on the spawning ground and transport processes during the early life stages are also recognized as potentially important controlling factors for the recruitment of common squid in the following season. Based on biological and oceanographic information we collected from field sampling and modeling studies, we forecasted locations of spawning and feeding grounds, and its abundances up to 2050 using MPI model under climate change scenario SRES A1B.

**C1-6309**

## Fluctuation on fish fauna in the east southern sea of Korea during 2006-2009

Jung Hwa **Ryu**[1], Jin Koo Kim[2] and Dong Seon Kim[3]

[1] Ryujunghwa Marine Research Institute, 444-10 Gaya 3-dong, Busan, 614-803, R Korea. E-mail: okdom-ryu@hanmail.net
[2] Department of Marine Biology, Pukyong National University, Busan, R Korea
[3] Pukyong National University, Busan, R Korea

In order to estimate the response of marine ecosystem with climate change, we have been monitoring fish species composition in the east southern sea of Korea during 2006-2009 using shrimp trawl. A total of 79 species was collected, of which cumulative number of fish species was 48 species in 2006, 65 in 2007, 71 in 2008 and 76 in 2009. It showed a rapid increase until 2007, but slight increase since then. The dominant species in the number of individuals were *Apogon lineatus, Engraulis japonicus* and *Conger myrister* in 2006, *A. lineatus, C. myrister* and *Chelidonichthys spinosus* in 2007, *C. myrister, A. lineatus* and *Sebastes thompsoni* in 2008, *Clidoderma asperrimum, Acropoma japonicum* and *C. myrister* in 2009. The dominant species in biomass were *Okamejei kenojei, C. myrister* and *C. spinosus*, but *C. asperrimum* was newly dominant species in 2009 unlike the former years. Comparing to the results by Youn and Shim (2000) conducted in the same area but in 1999, subtropical fishes, *Aulopus japonicus, Epinephelus septemfasciatus, Kaiwarinus equula, Leiognathus elongatus* and *Chaetodon modestus* were newly found in recent years, resulting from the climate change.

**C1-6378**

## Reasons for high vulnerability of coastal fishing communities of Baja California (Mexico) and potential adaptation strategies to climate change

Salvador **Lluch-Cota**, René Kachok and María Verónica Morales-Zárate

Fisheries Ecology, Centro de Investigaciones Biologicas del Noroeste (CIBNOR), Mar Bermejo No. 195, Col. Playa Palo de Sta. Rita, La Paz, Baja California Sur, 23000, México. E-mail: slluch@cibnor.mx

West coast of Baja California, Mexico, hosts an interesting fishing system because it combines the presence of highly valued fish products (abalone and lobster), management rules that include long term concessions and exclusive fishing rights, and a sophisticated organization of fisherman (in cooperatives, and a cooperatives federation). At present the system can be considered relatively successful in terms of sustainability; however, we believe it's particularly vulnerable to climate change. Through retrospective and modeling analyses, we propose that a) their main fishing resource, abalone, has shown large abundance changes driven by temperature and food availability, b) the potential decrease of abalone abundance cannot be compensated by increasing fishing effort for the other high value resources, particularly the lobster, because of the predictable strong ecosystem impacts, and c) the concession system, the geographical isolation, and the fidelity to the activity could be strongly compromised if ecosystem changes occur, even if they are not related to fishing impacts. We propose a menu of adaptation strategies organized as specific actions that can be applied along the productive process, from the catch to the market (productive chain).

# C2 Oral Presentations



**28 April, 14:35 (C2-6018), Invited**

## Surfclam dramas and other stories about the human dimensions of climate change and fisheries

Bonnie J. **McCay**[1]

Department of Human Ecology, School of Environmental and Biological Sciences, Rutgers University, 55 Dudley Rd., New Brunswick, NJ, 08901, USA. E-mail: mccay@sebs.rutgers.edu

Research on climate change and the "coupled" socio-ecological system of the Mid-Atlantic Bight and its surfclam population, fishery, and management system has led to rethinking of the "human dimension" in climate change and ecosystem-based management. The standard ways of thinking about humans in relation to ecosystems include human activities and by-products as threats, whether discrete or cumulative (the "anthropogenesis" factor); humans as consumers of "ecosystem services" (including "valuation" and "tradeoff" analyses); and, from the social scientists, humans as those affected by environmental or—more likely—regulatory change (the "social impact" approach). Also there is the larger view of humans as "tragedians of the commons," reflecting the inadequacies and failures of our institutions for managing marine systems, where property rights are complex and fluid and jurisdictional boundaries rarely coincident with ecosystem properties.

Adding climate change to the mix suggests the inadequacy of these approaches due to the greater dynamics and uncertainties involved and also because of the need to look seriously at mitigation and adaptation. This situation adds some urgency to yet another perspective: people as thoughtful, interested, and differentially situated actors in "dramas of the commons," or situations in which people—for example, scientists, managers, vessel owners, factory workers—interact socially to try to deal with and correct the problems they experience and anticipate. Their institutions are extremely important to these efforts but so is their creativity and sociality. Our ongoing research on responses to climate change in a coupled marine system allows us to explore these multiple approaches to "human dimensions."

**28 April, 15:00 (C2-6021)**

## Food security, fisheries, and climate change

Serge M. Garcia, Andrew A. Rosenberg and Jake **Rice**

Fisheries and Oceans Canada, Ecosystem Science Directorate, Station 12S014, 200 Kent St., Ottawa, ON, K1A 0E6, Canada
E-mail: Jake.Rice@dfo-mpo.gc.ca

The World population is expected to grow from the present 6.8 billion people to about 9 billion by 2050, and a higher proportion will live in coastal communities. Desertification and increased number and intensity of severe storms associated with climate change poses a high risk of reducing crop and livestock production in many of the regions with high population density. The consequences for global and regional food security will affect fisheries among other sectors. The demand for nutritious and healthy food will increase the demand for marine and freshwater resources in both high-value markets and regions with poverty and high population density. However, these resources are already stressed to their maximum level of productivity and often beyond, by fishing, in a context of growing organic pollution, toxic contamination, coastal degradation, and climate change. Looking towards 2050, current ocean policies and governance needs to be reviewed relative to the role of oceans in meeting future food security needs. Current dialogue on appropriate levels for production from capture fisheries and aquaculture and balance between conservation of aquatic biodiversity and resource extraction rarely include serious discussion of future food security needs and the role of fish in meeting them. This paper tried to open the necessary dialogue. This paper will develop these points, providing an overview of regional and global food security needs, expected shortfalls from land-based food production, and the main drivers of change affecting the fishery and aquaculture sector. From this overview we sill suggest how new science, policies and interventions could best address those challenges, and the types of dialogues that need to open in policy and governance to allow greater progress to be made.

**28 April, 15:15 (C2-6282)**

## Citizen science as a research tool for monitoring ecological change in the marine environment

Gretta **Pecl**[1], Rebecca Brown[1], Peter Walsh[1], Stewart Frusher[1], Graham Edgar[1], Jeremy Lyle[1], Elvira S. Poloczanska[2] and Rick Stuart-Smith[1]

[1] Tasmanian Aquaculture and Fisheries Institute, Private Bag 49, University of Tasmania, Hobart, Tasmania, 7001, Australia
E-mail: Gretta.Pecl@utas.edu.au
[2] Climate Adaptation Flagship, CSIRO, P.O. Box 120, Cleveland, Queensland, 4163, Australia

A major challenge in establishing how climate change may be impacting on our marine ecosystems, particularly in Australia, is the scarcity of ecological monitoring programs that inform us of such changes. Tasmania has a relatively large fishing industry, high participation rate in recreational fishing, and a high number of other individuals utilising marine waters, *e.g.* boaters and scuba divers spending many hours around the water potentially providing observations at low cost. We have developed a web-based on-line database and mapping facility (REDMAP – Range Extension Database and Mapping project) where members of the public submit data on catches/observations of key species that may be impacted by climate change. Range extensions in Tasmania have already been recorded in barnacles, sea urchins and dozens of fish species. Volunteer recording schemes or 'citizen science' projects, can generate considerable amounts of valuable information for researchers, involve communities, and raise public awareness of conservation issues. Community participation in REDMAP can create for individuals the sense (and in this case, the reality) that they are actively and constructively helping with a major issue currently facing the global community – people can log on and literally see 'their' data point on the map. Making the community aware of climate change issues in the marine context is a challenge as the impacts are less visible in comparison to 'dry rivers' and 'forest dieback'. REDMAP is greatly assisting in raising awareness and engaging participants in our fishing industries, improving industry and community understanding of the impacts of climate change on marine biodiversity and resources.

**28 April, 15:30 (C2-6300)**

## Will diversity assist adaptability? A case study contrasting diverse and specialized fishing sectors in the Queensland Inshore Fishery, Australia

Renae C. **Tobin** and Stephen G. Sutton

Fishing and Fisheries Research Centre, James Cook University, Townsville, Queensland, 4811, Australia
E-mail: renae.tobin@jcu.edu.au

In the face of climate change, fisheries should be aiming to become more diverse, rather than specialized. A diverse fishery is likely to be more adaptable to change in species distribution and availability resulting from climate change. Traditional fisheries management, however, has aimed to increase economic efficiency and improve ease of management through encouraging fisheries to be dominated by a few large operators targeting single species. Using the Queensland (Australia) Inshore Fishery as a case study, this project shows how a diverse fishing sector is likely to be more adaptable to climate change. The Commercial Inshore Fishery on Queensland's east-coast contains a diverse array of operators. Fishers harvest a diverse range of species and markets are available for byproduct species as well as the main target species, suggesting fishers should be able to easily adapt to environmental factors that impact the availability of one inshore species by shifting their effort to readily available substitutes. Most commercial fishers also operate in more than one fishery, meaning they are able to shift effort to other fisheries if needed. In contrast, Inshore Charter fishers are highly specialized, with a high dependence on a single species (barramundi) within a limited area. Further, most charter fishers are dependent solely on the Inshore Fishery, suggesting limited capacity to diversify into other fisheries if needed. The contrasting characteristics of these two sectors suggest a very different capacity to adapt to change.

**28 April, 15:45 (C2-6098)**

## Economic strategies for avoiding climate change effects on Japanese salmon fisheries

Ikutaro **Shimizu**[1], Tsutomu Ohnuki[2] and Kunio Abe[2]

[1] Fisheries Economy Division, National Research Institute of Fisheries Science, 2-12-4 Fukuura, Kanazawa-ku, Yokohama, Kanagawa, 236-8648, Japan. E-mail: ikutaro@affrc.go.jp
[2] Obihiro Field Station, National Salmon Resources Center, 441-55, Taisho-cho, Obihiro, Hokkaido 089-1242, Japan

Salmon are important fishery resources with global commercial value. It is thought that global warming will have a marked influence on salmon inhabiting subarctic waters. Salmon fisheries are an important industry in northern Japan, so it is necessary to examine strategies for global warming effects from an economic viewpoint. The demand for seafood is increasing globally; however, there is a risk that the stability and yield of cold-water fisheries resources will decrease due to global warming, causing prices to rise and pricing salmon out of global markets. The results of investigations of salmon fisheries in Hokkaido suggest the cornerstones for building economic strategies to be 'stability of resources' and 'prices.' Cushioning salmon fisheries against the effects of global warming may be enabled by a combination of local, regional and global economic strategies. Local strategies; (1) saving fishing profits in rich years and using them as funds for lean years, (2) developing local resources to complement more regional resources, (3) maintaining prices of local resources by cooperation between salmon hatcheries, set-net fisheries, and seafood processing industries. Regional strategies; (4) planning the coexistence of hatchery salmon and wild salmon and letting both resources stabilize, (5) examining methods of raising the return rate of salmon, based on joint Japanese and Russian observation of the Okhotsk Sea. Global strategies; (6) planning differentiation by eco-labeling to evaluate hatchery salmon in the global market, (7) regarding eastern Asia as an extension of the Japanese market. These seven strategies are likely to help to improve the basis of fisheries management.

**28 April, 16:20 (C2-6185), Invited**

## Climate change, fisheries and aquaculture in the Pacific – Implications for food security, livelihoods and economic growth

Johann D. **Bell**

Strategic Engagement, Policy and Planning Facility, Secretariat of the Pacific Community, B.P. D5, Noumea Cedex, 98848, New Caledonia
E-mail: johannb@spc.int

The extent to which fisheries underpin food security, livelihoods and economic growth throughout the Pacific is astounding. Fisheries provides 51-94% of the animal protein for people in coastal areas, where annual per capita fish consumption often exceeds 75 kg and 60-90% of fish is derived from subsistence fishing. They are also a widespread source of income – 53 % of coastal households catch and sell fish; and thousands are employed on tuna vessels, or in tuna canneries. Fisheries are vital to national economies - sale of licence fees to distant water fishing nations to catch tuna contribute 4.4-41.7% of government revenue for seven Pacific island counties and territories.

But these benefits are at risk. Due to rapid population growth, a gap is emerging in the fish needed for food security and the harvests available from coastal fisheries. Also, preferred access to European markets for Pacific tuna cannot be expected to last indefinitely. Plans to make the benefits of fisheries in the Pacific resilient to such drivers are underway. However, climate change could derail these plans. This presentation addresses some key questions, including: How will communities cope as the projected degradation of coral reefs widens the gap between supply and demand in coastal fisheries? Will climate change reduce or improve access to tuna as means of filling the food security gap? Will the expected changes in rainfall affect the ability of rural communities to engage in small pond aquaculture? Which countries will be winners or losers in terms of employment, GDP and government revenue from the expected changes in the distributions of tuna?

**28 April, 16:45 (C2-6346)**

## Adapting to climate change – Lessons from the Peruvian anchovy fishery on how to cope with extreme climatic events and environmental variability

Milena **Arias-Schreiber**[1], Miguel Ñiquen[2] and Marilou Bouchon[2]

[1] Leibniz Center for Tropical Marine Ecology, Fahrenheitstrasse 6, Bremen, 28359, Germany. E-mail: milena@uni-bremen.de
[2] Peruvian Marine Research Institute, Esq. Gamarra y Gral.Valle s/n, Chucuito, Callao, Peru

The Peruvian anchovy fishery is the largest worldwide in terms of catches. Starting during the mid 1950s, this fishery has been highly dependent on drastic natural stock fluctuations due to the sensitivity of pelagic fish to ocean-climate variability. Beyond seasonal changes, the fishery bears important yearly variability due to El Niño Southern Oscillation events (ENSO) which affect Peruvian coasts in irregular intervals and magnitude. Since the 1950s, three extreme ENSOs have been recorded in Peru in 1972-73, 1983-84 and 1997-98. This study presents a list of adaptations of the commercial anchovy fishery to the mentioned events in an attempt to improve the resilience of the fishing industry. Some coping strategies were attempted in 1972-73, however an evident reduction of impacts was mainly observed during the 1997-98 ENSO. The strategies included: (a) instalment at several bays of fish reduction factories and unloading capacities strategically distributed along the Peruvian coast, allowing changes in fishing effort following stock migrations; (b) opportunistic use of invading fish populations when anchovy is not available; (c) an adaptive management based on flexible formal institutions avoiding those legal instruments that could restrict or delay decision processes; and (d) reduction of market price uncertainty through massive investments of fishing companies in technology for quality improvement of fishmeal, and subsequent decoupling from soybean or other protein-rich substitutes prices. Although our list is not exhaustive, it presents a concrete example on how governments and societies can develop strategies to cope with uncertain change impacting the availability and supply of natural resources.

**28 April, 17:00 (C2-6122)**

## In search of new sea legs: Women's roles in the survival of Japan's fishing industry

Satsuki **Takahashi**

Department of Anthropology, Rutgers University, 131 George St., New Brunswick, NJ, 08901-1414, USA
E-mail: satsuki@eden.rutgers.edu

Seven fishermen's wives in a coastal town opened a vendor's booth to sell fresh and processed fish on Sundays in a corner of their local co-op's fish market to support their local fishing industry, particularly as it has been struggling with declining landings. The idea of opening a booth was first suggested by prefectural fisheries advisors; it was then carried out by volunteers from the co-op's Women's Association. The fisheries advisors' idea of women's seafood vendor business was associated with the national Fisheries Agency's interests in revitalizing seafood consumption in Japan as well as in promoting financial survival strategies for local fishers even as the Agency was cutting government subsidies for the fishing industry. As part of these efforts, officials have been increasingly interested in the role of the women from fishing families, or "*Hama no kāchan*" (coastal moms), who might act as a force for the declining fishing industry by gaining some traction in promoting domestic seafood consumption. Most of the women who volunteered for the vendor business said that their main reason for doing so was to help their family's financial situation, but that they also hoped to revitalize the troubled fishing industry. Based on ethnographic research on survival strategies in small coastal fishing co-ops, this paper will examine how the gendered division of labor can be mobilized in support of changing state goals.

**28 April, 17:15 (C2-6055)**

## Traditional fisheries practices and adaptation to environmental change: Case studies from Alaska and Brazil

Henry P. **Huntington**[1], Alpina Begossi[2] and Renato A.M. Silvano[3]

[1] Pew Environment Group, 23834 The Clearing Dr., Eagle River, AK, 99577, USA. E-mail: hhuntington@pewtrusts.org
[2] UNICAMP and Fisheries and Food Institute, Rua Cel Quirino, 1636 Campinas SP, Brazil
[3] Depto. Ecologia/ UFRGS, CP 15007, 91501-970 Porto Alegre – RS, Brazil

Local and traditional knowledge has contributed to fisheries biology and ecology by providing otherwise unavailable information, by helping create hypotheses, and in various other ways. The use of such knowledge and the engagement of its holders have contributed to fisheries management by improving the knowledge base for management decisions, by increasing support among fishers for management efforts, by identifying new regulatory approaches, and in other ways. To date, however, relatively few efforts have been made to use traditional knowledge and traditional practices as the basis for adaptation to environmental change. We explore case studies from Alaska and Brazil to examine the how drawing on traditional practices can enhance detection of and resilience and adaptation to environmental change from climate change, invasive species, pollution, water diversion, and other factors. Specifically, traditional knowledge and practices can allow rapid adjustment of harvest depending on environmental conditions, provide a margin of safety to prevent overharvest, lead to new harvest practices that reflect changing conditions, allow fishers to base decision on their expectations of ecosystem trends, and allow other adjustments to be made locally and quickly. Whether formal regulatory systems and the economic realities of the marketplace permit such changes is another question, but the connections between traditional practices and adaptation deserve more attention academically and in practice.

**28 April, 17:30 (C2-6318)**

## Fishers' local ecological knowledge about fish and climatic change

Renato A.M. **Silvano**[1,2], Henry P. Huntington[3] and Alpina Begossi[2,4]

[1] Depto. Ecologia/ UFRGS, CP 15007, 91501-970 Porto Alegre – RS, Brazil. E-mail: renato.silvano@ufrgs.br
[2] Fisheries and Food Institute, Rua Coronel Quirino 1636, Campinas, 13025-002, - SP, Brazil
[3] Pew Environment Group, 23834 The Clearing Dr., Eagle River, AK, 99577, USA
[4] Capesca- PREAC (Lepac) and CMU, CP 6023, Unicamp, SP, Brazil

Fishers' local ecological knowledge (LEK) has been applied to improve understanding on ecology, migration, temporal trends in abundance, feeding habits and reproduction of fishing resources worldwide. Climatic changes may affect coastal fish and fisheries, but the relationship between fishers' LEK and climatic changes is still poorly known. Our aim is to analyze the potential contribution of fishers' LEK to improve the current knowledge on fisheries related effects of climatic changes. We made a review of study cases at the Brazilian coast and Alaska, which used semi-structured interviews with small scale fishers through standardized questionnaires about seasonal abundance, migration, distribution and reproduction of coastal fishes and whales. We compared information gathered with young and older (40 years and over) fishers, linking fishers' LEK based data with possible climatic changes' effects on fish. We argue that fishers' LEK could be useful in two ways. First, it may serve as a baseline for comparison with future trends of resource abundance and distribution driven by climatic changes. Second, fishers' LEK may indicate changes already occurring, especially where these changes have been more pronounced and long lasting. However, fishers' perceptions regarding changes in fish abundance and other parameters (migration, reproduction) may be also related to short term environmental changes (pollution, habitat degradation) and overfishing. A major challenge will be to disentangle these causal factors from the effects of climatic changes. Nevertheless, fishers' LEK may be a useful source of information to understand and cope with climatic changes, especially in countries where scientific data is scarce.

**28 April, 17:45 (C2-6129)**

## The Lake Chilwa fishing household strategies in response to water level changes: Migration and conflicts

Friday J. **Njaya**

Fisheries Policy and Planning, Malawi Fisheries Department, Ring Rd., Capital Hill, P.O. Box 593, Lilongwe, Central, 593, Malawi
E-mail: fnjaya@gmail.com

In this paper, household strategies are examined in response to water level fluctuations of Lake Chilwa due to climate change. The frequency and patterns of migration of fishers, conflicts due to migration of fishers, and co-management are also analysed. The seasonal and periodic lake level changes affect livelihoods of the households. As coping and adaptation strategies, the households depend on fishing in pools of water located in influent rivers and hunt birds for income and food while others migrate elsewhere to work as casual labourers. When the lake rises during the rainy season, inundated areas become suitable for production of maize and rice. However, when the floods recede in the dry season, farming of winter maize and vegetables is common. Moreover, migration of fishers is common around Lake Chilwa. The pattern of migration varies according to the season and gear type. Conflicts emerge due to the seining operations, which require removal of aquatic vegetation. The conflicts are in various forms including access to fishing grounds, authority to grant access to fishing areas and fish price competition between the local fishers and migrants. Finally, the household strategies towards recovery of the fishery after the water has receded are inherent within the households' traditional system. A diversified occupational change involving fishing, farming and trading is necessary. Since these households are dependent on the availability of fisheries, it is thus imperative to promote maximum resource exploitation in between periods of low lake level and to encourage a complete stop to fishing during periods of low water level.

**28 April, 18:00 (C2-6159)**

## Building community adaptability through ecosystem approach planning in the Province of Aurora, Philippines

Pedcris M. **Orencio**[1] and Masahiko Fujii[2]

[1] Division of Environmental Science Development, Graduate School of Environmental Science, Hokkaido University, N10W5, 060-0810, Japan. E-mail: pedorencio@ees.hokudai.ac.jp
[2] Graduate School of Environmental Science, Faculty of Environmental Earth Science, Hokkaido University, N10W5, 060-0810, Japan

Ecosystem planning is planning within the context of the area's available resources; the constraints accompanied with the use of the resource and the opportunities that come with the proper use of the resources. In the advent of climate change, undertaking ecosystem approach planning within the context of a province, which has a unique natural resource base such as Aurora, will provide measures on how to build adaptive mechanisms for vulnerable communities. Using existing available data, such as topographic and satellite maps, and previous resource assessment surveys and environmental profiling activities conducted, the researcher assessed the nature of the resource base. The assessments were then presented with community stakeholders and decision makers in order to validate and analyze the assessment conducted, and formulate strategic actions that aimed to optimize opportunities for sustainable management which is anchored in adaptive planning. Results showed that the province's opportunities lie on its social capital and its natural resource base and that inter-local cooperation in managing a common resource should be strengthened to ensure integrated management of the resource base.

**28 April, 18:15 (C2-6207)**

## Household fishermen empowerment based on local community wisdom as a problem solver on fishermen poverty: Case study in Madura Strait, Indonesia

Sahri **Muhammad**, Pudji Purwanti and Aida Sartimbul

Faculty of Fisheries and Marine Sciences, University of Brawijaya, Jalan Veteran, Malang 65145, Indonesia
E-mail: aida@brawijaya.ac.id; aidasartimbul@yahoo.com

Poverty is still the main threat for small scale fishermen because of their relatively small asset value. Various empowerment programs have been conducted by the government, however the results fall far below expectations. Therefore the aim of this study are: (1) to study the potential of pentagon asset and heptagon access to response current empowerments, (2) to assess the approach effectively that may cause the failure of empowerment, (3) to create the social and economic household fishermen empowerment model design as their community characteristics. Study methods were survey method and poverty rapid appraisal (PRA). The primary data were collected from fishermen household using participatory poverty assessment (PPA) and sustainable livelihoods approach (SLA). The results show that (1) asset value and social access are relatively high, (2) former empowerment based on co-management model with consultative type was found to be government-dominated and therefore with low community participation, (3) this study offers an alternative empowerment model based on local community wisdom with autonomy, participation, partnership, and various social community condition considerations.

# C2 Posters

## C2-6086

### Impact of climate change on livelihood and food security of artisanal fisherfolks in Lagos State, Nigeria

Siyanbola Adewumi **Omitoyin**[1], Tosan Fregene[2] and Dontsop Paul[3]

[1] Department of Animal Science and Fisheries Management, Bowen University, Iwo, PMB 284, Nigeria. E mail: sbomitoyin@yahoo.com
[2] Department of Wildlife and Fisheries Management, University of Ibadan, Ibadan, Nigeria
[3] Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria

The artisanal fishery which is basically rural, occupies a significant position in the Nigerian economy providing employment for about 5.8% of the Nigerian population and supplying 81.9% of the total domestic fish production. However, climate change is already modifying the distribution of fish species with changes in habitat size, species diversification and productivity. Fish supply from this sub-sector has thus continued to decline. The study, therefore, examined the impact of climate change on livelihood and food security of artisanal fisherfolks in Lagos State, Nigeria.

A stratified sampling technique was used to select 58 lagoon, 15 coastal and 15 riverine fishing communities in Lagos State. A total of 311 respondents were interviewed using structured questionnaire. Data collected include socio-economic characteristics, livelihood parameters, fish species and productivity data while climatic data was obtained from the weather station and meteorology department. Data were analyzed using descriptive statistics and stochastic frontier catch function analysis. The result of the analysis showed that there were changes in temperature and rainfall pattern which is a deviation from the normal trend. Variation in species diversity and abundance was also observed. There were other sources of livelihood engaged in either as primary or secondary occupation. The technical efficiency of the gears used among the fisherfolks in lagoon was 26.4%, coastal 80% and riverine 52.9%. There is the need to put in place strategies that will mitigate the effect of climate change by improving access to micro-credit, use of better gear, reduction in fish loss through effective methods of preservation and value addition to their products. Coping strategies which include alternative sources of livelihood can also be encouraged.

## C2-6140

### Modeling energy consumption efficiency of fisheries: What to gain by effort displacement? The case of Danish Skagerrat-Kattegat fisheries

Francois **Bastardie**, J. Rasmus Nielsen, Bo Sølgaard Andersen and Ole Eigaard

Department of Marine Fisheries, Danish Institute for Fisheries Research, Charlottenlund Castle, Technical University of Denmark, DK-2920, Charlottenlund, Denmark. E-mail: rn@aqua.dtu.dk

The global concern about reduction in $CO_2$ emissions leads to question the fishery catch sector by cutting the large fuel consumption that constitutes a major part of the cost of fishing. Efficiency in energy use, *i.e.* the amount of fuel needed to catch one kilogram of fish, is first calculated and its dependency on particular fishing practices evaluated. Observed spatial and seasonal pattern of fishing effort is then considered against two alternative effort re-allocation scenarios for presumable fisher's adaptation: (A) preferring smaller catches (maybe less value) nearby over larger catches (possible higher value) farther off, and (B) shifting toward fisheries targeting closer stocks from their designated harbours. Effort scenarios were tested by developing an individual-based model for modeling fishing vessel movements in interaction with the underlying spatio-temporal distribution of the resources, this latter informed from scientific surveys. Vessel-based fuel consumption and energy efficiency were computed over the year 2005-2009 after coupling high resolved spatial and temporal effort data with logbook catch declarations, sales slips, vessel engine specifications, and fish and oil price time series. These indicators were further detailed at the fishery scale by classifying fishing trips into various aggregations of fleet-segments. Results of scenarios are compared to the historic effort pattern allocation and possible fuel saving and energy efficiency improvement is highlighted when effort is displaced toward less valuable stocks but closer to the ports. Possible side effects on stock dynamics of concentrated fishing pressure on certain areas are also investigated.

**C2-6155**

## The role of the academe in undertaking research and developing management strategies to address climate change impacts on fisheries: Some examples of initiatives of academic institutions in the Philippines

Michael D. **Pido**[1], Ruth Guzman[2], Maripaz L. Perez[3], Elvira Martija[4], Elen R. Basug[5] and Len R. Garces[3]

1 Center for Strategic Policy and Governance, Palawan State University, G/F Medical Bldg, Tiniguiban Heights, Puerto Princesa City, Palawan, 5300, Philippines. E-mail: mdpido@yahoo.com
2 Rizal Technological University, Metro Manila, Philippines
3 WorldFish Center, SEARCA Office, Laguna, Philippines
4 Eastern Visayas State University, Leyte, Philippines
5 Environmental Management Bureau, Quezon City, Metro Manila, Philippines

The active participation of relevant stakeholder groups is critical to effectively address climate change impacts on fisheries' production and distribution. The academe's role as a stakeholder is quite important in conducting relevant research and developing appropriate adaptation and mitigation strategies. This paper aims to describe two research works related to climate change being undertaken by the state universities and colleges (SUCs) in the Philippines. Led by the Philippine Association of Tertiary Level Educational Institutions in Environmental Protection and Management, several SUCs in Region 8 were involved in documenting good practices and adaptation strategies to climate change related to fisheries. Manifestations of climate change impacts are greater frequency of harmful algal blooms (HABs) and coral bleaching among others that have resulted in decrease in fish catch from 30 metric tons/year to 26 metric tons/year. Monitoring of relevant HAB and coral parameters are suggested as protection strategies while change of fishing grounds is forwarded as an accommodation strategy. Spearheaded by the WorldFish Center (international fisheries research organization), several SUC were engaged in evaluating relevant fisheries' threats. Climate change was identified as a 'high risk' threat, with a high impact and high likelihood of occurrence. It was also identified as a cross-cutting issue although its relevance varies from being a motor factor (active element with predictable impacts) into being simply a symptom element that is greatly influenced by other elements. These illustrative examples show that the academe could play a crucial role in generating useful information to developing relevant measures to address climate change impacts on fisheries.

**C2-6169**

## "Bringing it all together" – A multi-disciplined, collaborative approach to preparing fisheries and aquaculture for climate change in South Eastern Australia

Ingrid L. **Holliday**

Program Coordinator, GPO Box 4440, VIC, 3001, Australia. E-mail: Ingrid.L.Holliday@dpi.vic.gov.au

The south eastern Australian marine region is considered to be a global marine 'hotspot' for climate change. Temperatures in the region have risen and continue to rise more rapidly than elsewhere in Australia, and possibly the Southern Hemisphere. Such oceanographic changes are predicted to directly affect marine resources, leading to social and economic flow-on effects for reliant businesses and communities. Changes to the range or abundances of resources will provide particular challenges for resource managers of the five separate jurisdictions in the region. The implications of these changes will depend on how well prepared governments, research organisations, and fishing and aquaculture sectors are to respond.

Stakeholders in the region are responding to the climate change challenge through a collaborative, multi-disciplined program. This is the first program of its kind in Australia involving multiple jurisdictions aimed at coordinating research, development, extension, and policy relating to marine resources. The program is guided by an adaptation framework that assists in bringing together information on exposure and sensitivity to understand likely impacts. It also considers adaptive capacity in informing overall vulnerability and provides a risk based approach for evaluating adaptation strategies for both the sectors and for resource managers.

This presentation is provided on behalf of the program partners. It will outline how the adaptation framework is being used in South Eastern Australia, information about likely impacts and challenges in this 'hotspot' region, and particularly, the steps being taken to prepare fisheries and aquaculture businesses and communities, and resource management for future change.

**C2-6172**

## Could management react to a changing climate? The case of the Japanese small pelagic fishes

Felipe **Hurtado-Ferro**, Sachihiko Itoh and Kunio Shirakihara

Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
E-mail: felipehurtado@nenv.k.u-tokyo.ac.jp

Small pelagic fishes are valuable marine resources of Japan, as well as highly variable ones. Record catches for the Japanese sardine (*Sardinops melanostictus*) were registered during the late 80's, but a four-year recruitment failure led to severe stock depletion and have been in low level since then; on the contrary, Japanese anchovy (*Engraulis japonicus*) stock has increased steadily declining slightly on the last 4 years.

**C2-6178**

## Potential impacts of climate change on Japanese scallop aquaculture: A case study in Funka Bay, Hokkaido, Japan

I Nyoman **Radiarta**[1,2], Sei-ichi Saitoh[1] and Toru Hirawake[1]

[1] Laboratory of Marine Environment and Resource Sensing, Faculty of Fisheries Sciences, Hokkaido University, 3-1-1 Minato, Hakodate, Hokkaido, 041-8611, Japan. E-mail: radiarta@salmon.fish.hokudai.ac.jp
[2] Research Center for Aquaculture, Agency for Marine and Fisheries Research, Ministry of Marine Affairs and Fisheries, Jl. Ragunan 20, Pasar Minggu, Jakarta, 12540, Indonesia

Evidence has been accumulating in recent years that suggest climate change might drive changes in aquaculture development. Sustainability of scallop production is also influenced by changes of environmental conditions. Climate change presents unquantifiable threats in the forms of increased temperatures, extreme weather and diminishing water supplies. In this study, to model the potential impact of climate change on the scallop aquaculture, we carried out a two-step analysis. First, we analyzed the suitability of sites for Japanese scallop aquaculture using an integrated remote sensing and geographic information system (GIS)-based model. Multi-criteria evaluation was adapted to the GIS models in order to rank sites on a 1 (least suitable)-to-8 (most suitable) scale. Second, in the site selection analysis, we examined the potential climate change impacts using the sea surface temperature (SST) values of 1°C, 2°C, or 4°C. These three SST values were selected based on the fourth assessment report of the IPCC. By increasing the SST values, we found that the most suitable sites (score 8) indicated slight (26.4%), significant (14%) and drastic (0.01%) changes compared with the original model (29%), respectively. These prediction models showed that climate change, by altering the physical characteristics of suitable cultivation areas, can have detectable impacts on the development of scallop aquaculture. The models also indicated that climate change might have an important impact on the future development of marine aquaculture in this region, a prospect that will need to be considered.

**C2-6281**

## Australian National Climate Change Adaptation Research Network for Marine Biodiversity and Resources

Neil Holbrook[1], Gretta **Pecl**[2], Alistair J. Hobday[3] and Stewart Frusher[2]

[1] School of Geography and Environmental Studies, University of Tasmania, Hobart, Tasmania, 7001, Australia
[2] Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Hobart, Tasmania, 7001, Australia
E-mail: Gretta.Pecl@utas.edu.au
[3] CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania, 7001, Australia

The Australian National Climate Change Adaptation Research Network for Marine Biodiversity and Resources (ARN-MBR, or the Marine Adaptation Network) is an interdisciplinary network that is building adaptive capacity and adaptive response strategies for the effective management of marine biodiversity and natural marine resources under climate change. The central aim is to lead Australia's efforts in understanding and adapting to today's emerging climate change needs, while also providing the training ground for the development of tomorrow's interdisciplinary climate change researchers. The network fosters collaborative and creative interdisciplinary research, data-sharing, communication and education, and helps advance and document climate change adaptation knowledge so that policy and decision-makers can develop appropriate climate change adaptation strategies to build adaptive capacity. The network comprises a holistic framework that cross-cuts climate change risk, marine biodiversity and resources, socioeconomics, and policy, and includes ecosystems and species from the tropics to Antarctic waters. The Network has been developed around five interconnecting marine themes (integration, biodiversity and resources, markets, communities, and policy) that address and respond to cross-cutting issues. Network initiatives include national workshops to synthesise existing and emerging research and identify knowledge gaps, a database repository for data-sharing, interactive tools (*e.g.* searchable on-line databases; case studies; links to research projects; toolkits for stakeholders to respond to climate change risks) and summer/winter schools for postgraduate students and early career researchers in climate change adaptation. We invite you to be part of this inclusive network, open to all marine researchers, stakeholders and end-users. Registration can be completed online at www.nccarf.edu.au/marine/.

# D2 Oral Presentations

**28 April, 14:35 (D2-6117), Invited**

## Global change projection for ocean biogeochemistry and ecosystem

Michio **Kawamiya**

Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, 3173-25 Showamachi, Kanazawa-ku, Yokohama, 236-0001, Japan. E-mail: kawamiya@jamstec.go.jp



The protocol for global warming projection for IPCC AR5 has two target time scales: decadal and centennial. For the decadal time scale, global models with a high horizontal resolution of (50-100 km for the atmosphere, ~30 km for the ocean) are desirable. For the centennial time scale, GCM-based earth system models with a moderate horizontal resolution (~250 km for the atmosphere, ~100 km for the ocean) will be adopted to consider interactions between climate change and biogeochemical processes significant for this time scale. One of the main foci for the decadal timescale projection is predictability of the Pacific Decadal Oscillation (PDO). Preliminary studies showed that there is a certain degree of predictability for PDO, which may have important implications on fisheries since PDO is known to have significant impacts on ocean ecosystem. High resolution ocean models adopted for decadal projection will also enable the assessment of impacts on fisheries due to changes in Kuroshio and frontal structures. On the other hand, many of the models for centennial timescale projection will incorporate carbon cycle components, meaning that the outputs will allow the assessment of future productivity and the impact of ocean acidification. Preliminary results suggest that phytoplankton productivity is significantly reduced due to stratification especially in the equatorial Pacific. Data dissemination systems are expected to be improved in the next round of IPCC assessment both domestically and internationally, with the hope that even more scientists, including fisheries scientists, will be able to investigate the impacts of global warming using projected data.

**28 April, 15:00 (D2-6325)**

## Decadal variability in the oceanic frontal zones in the western North Pacific Ocean in an eddy-resolving OGCM

Masami **Nonaka**[1], Bunmei Taguchi[2], Hideharu Sasaki[2] and Hisashi Nakamura[1,3]

1 Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, Yokohama, Kanagawa, 236-0001, Japan
E-mail: nona@jamstec.go.jp
2 Earth Simulator Center, Japan Agency for Marine-Earth Science and Technology, Yokohama, Kanagawa, 236-0001, Japan
3 Graduate School of Science, The University of Tokyo, Tokyo, Japan

The western North Pacific (NP) region is known as one of the centers of Pacific decadal variability, and air-sea interactions in the region may have a key role to induce or intensify the decadal variations. Recent studies have revealed the possible importance of oceanic frontal zones to feedbacks from the ocean to the atmosphere. We have investigated variations in the oceanic frontal zones based on a hindcast integration of an eddy-resolving OGCM. We find that the corresponding decadal sea surface temperature anomalies in the western NP region have their maxima along the Oyashio Extension (subarctic) frontal zone, while sea surface height (SSH) anomalies are most prominent along the Kuroshio Extension (KE) frontal zone. In association with the SSH variations, the KE Current has decadal variations in latitude of its axis and also in its strength. Although large-scale SSH variations associated with those decadal variations can be explained by propagation of wind-driven Rossby waves, there are also small meridional-scale variations (*i.e.*, frontal-scale), which cannot be directly explained by large-scale wind-stress variations. For formation of the frontal-scale variations accompanying the decadal variations in the KE Current strength, we suggest the possible importance of advection of high (low) potential vorticity water to the north (south) of the KE Current. In the OGCM simulation, the KE Current strengthens at the end of 1980s, when number of Japanese sardine started to decrease, implying some influence of the KE Current variations on the ecosystem in the western NP.

**28 April, 15:15 (D2-6209)**

## Simulating lower trophic level ecosystem dynamics in the Bering Sea

Georgina A. **Gibson**[1], Kate Hedström[2], Enrique N. Curchitser[3] and Albert J. Hermann[4]

[1] International Arctic Research Center, University of Alaska Fairbanks, P.O. Box 757340, Fairbanks, AK, 99775-7340, USA
E-mail: ggibson@iarc.uaf.edu
[2] Arctic Region Supercomputing Center, University of Alaska Fairbanks, 909 Koyukuk Dr., Suite 105, P.O. Box 756020, Fairbanks, AK, 99775-6020, USA
[3] Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ, 08901-8525, USA
[4] Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, 3737 Brooklyn Ave. NE, P.O. Box 355672, Seattle, WA, 98105-5672, USA

Despite frequently being ice covered until March, the continental shelf of the eastern Bering Sea is one of the world's most productive marine ecosystems, with its fisheries representing half of the marine harvest in United States waters. Large changes in lower trophic level ecosystem dynamics have been observed on inter-annual and inter-decadal time scales, although the mechanisms giving rise to these changes are not well understood. We present a lower trophic level ecosystem model for the Bering Sea that has been developed to explore relationship between climate, ocean conditions, productivity and flow of energy through the food web. The core of the ecosystem model is a Nutrient-Phytoplankton-Zooplankton model which has been coupled to an ice-biology module and to a benthic sub-model. This modeling effort is a fundamental element of an integrated program to develop a forecast system for predicting the effects of future climate change on the ecosystem of the Bering Sea. Specifically, the integrated modeling effort aims to test the hypothesis that "Climate-induced changes in physical forcing of the Bering Sea will modify the availability and partitioning of food for all trophic levels of the shelf ecosystem through bottom-up processes". We illustrate the models ability to capture observed differences in plankton biomass, productivity and energy flow through the food web during a 'cold' year and a 'warm' year.

**28 April, 15:30 (D2-6324)**

## Roles of the *in-situ* observations in the detection of the Kuroshio frontal variability south of Japan

Yasumasa **Miyazawa**[1], Xinyu Guo[1,2], Ruo Chao Zhang[1], Sergey M. Varlamov[1], Tomowo Watanabe[3], Takashi Setou[3] and Daisuke Ambe[3]

[1] Research Institute for Global Change, JAMSTEC, Kanazawa-ku, Yokohama, Kanagawa 236-0001, Japan
E-mail: miyazawa@jamstec.go.jp
[2] Center for Marine Environmental Studies, Ehime University, Matsuyama, Ehime, 790-8577, Japan
[3] National Research Institute for Fisheries Science, Fisheries Research Agency, Kanazawa-ku, Yokohama, Kanagawa, 236-8648, Japan

We have investigated the sensitivity of including *in-situ* observations on the quality of the ocean reanalysis produced by a data assimilative eddy-resolving ocean model, with an emphasis on the Kuroshio frontal variability south of Japan. By increasing the number of the *in-situ* hydrographic profiles for the data assimilation, more enhanced Kuroshio front variations with approximately 20 days time scale were reproduced. The enhanced features exhibited the wavelike disturbances east of the Kii Peninsula with the wave length of 400 km and considerably affected coastal areas through the consequent warm water intrusion, which were consistent with the observed phenomena. Another kind of the warm water intrusion with the period of approximately 50 days associated with the Kuroshio small meander paths was well reproduced by the reanalysis. The addition of the in-situ profiles into the reanalysis did not change the intensity of these intrusions but did change their spatial patterns. This study suggests that the combined use of operational *in-situ* observations in coastal regions south of Japan and their assimilation into the ocean model is effective to capture the Kuroshio frontal variability.

**28 April, 15:45 (D2-6357)**

## From a climate to a multi-scale earth system model: Technical issues and advances

Enrique N. **Curchitser**[1], Kate Hedström[3], William Large[2] and Jon Wolf[2]

[1] Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ 08901, USA
E-mail: enrique@marine.rutgers.edu
[2] National Center for Atmospheric Research, 1850 Table Mesa Dr., Boulder, CO, 80305, USA
[3] Arctic Region Supercomputing Center, University of Alaska Fairbanks, 909 Koyukuk Dr., Suite 105, Fairbanks, AK, 99775, USA

Traditional climate models were not designed to naturally incorporate ecosystems and human activity as an integral part of the model solution. Part of the challenge is a result of the disparate relevant scales between the physics and biology. Furthermore, as interest is rising in regional climate impacts, it is becoming necessary to span a wider range of scales in both physics and biology. In this paper we present a climate model with a multi scale ocean component that is designed to both resolve coastal and shelf processes and incorporate lower and higher trophic level ecosystem models in a climate-scale simulation. The physical model is based on the NCAR CCSM global model and the ROMS regional ocean model. We present some of the technical issues in developing such a system. We will also discuss issues related to both down- and up-scaling and their relevance to the modeling of ecosystems.



**28 April, 16:20 (D2-6123), Invited**

## Climate models and fisheries: Opportunities and challenges

Anand **Gnanadesikan**

NOAA Geophysical Fluid Dynamics Laboratory, 201 Forrestal Dr., Forrestal Campus, Princeton University, Princeton, NJ, 08540-6649, USA
E-mail: anand.gnanadesikan@noaa.gov

Global coupled climate models have the ability to produce solutions for changes to and variability within the earth system consistent with our understanding of this system as a mathematically consistent set of equations. This talk discusses some lessons that these models can provide for fisheries science. We focus on a number of areas where GFDL's new earth system model shows considerable variability in primary productivity or interesting changes under global warming. The model highlights the importance of salinity variability in setting productivity and demonstrates that the mechanisms producing such variability can be driven by small-scale changes in wind that are not necessarily related to classically defined climate modes. This lesson is reinforced when looking at small-scale variability in wind patterns, such as have been linked to variability in the California Current region. Also noted are challenges implicit in modeling the earth system- highlighting a number of areas where our understanding of the basic physics and biology and hence of the underlying equations is weak. Physical oceanographic challenges include the exchange between the mixed layer and thermocline and the dynamics that ventilate the oxygen minimum zones- both of which may have implications for habitat structure. Biological challenges include the representation of how to link changes in the growth rate of phytoplankton (which the models should be able to simulate with some skill) to changes in zooplankton production. Implications of this for biases in the simulation of the annual cycle of productivity are also considered.

**28 April, 16:45 (D2-6323)**

## Interannual variations of 3D structures of lower-trophic-level ecosystems in the western North Pacific using a new marine ecosystem model based on an eddy-resolving data-assimilative OGCM

Kosei **Komatsu**[1,2], Naoki Yoshie[3], Shin-ichi Ito[4], Takahiko Kameda[5], Tsuneo Ono[6], Kiyotaka Hidaka[5], Toru Hasegawa[7], Akira Kuwata[4], Miwa Nakamachi[4], Yuji Okazaki[4], Takeshi Okunishi[5], Kazuaki Tadokoro[4], Hiroaki Saito[4] and Yasuhiro Yamanaka[8,9,10]

1 Graduate School for Frontier Sciences, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
E-mail: kosei@ori.u-tokyo.ac.jp
2 Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
3 Center for Marine Environmental Studies, Ehime University, 2-5 Bunkyo-cho, Matsuyama, 790-8577, Japan
4 Tohoku National Fisheries Research Institute, Fisheries Research Agency, 3-27-5 Shinhama-cho, Shiogama, 985-0001, Japan
5 National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa-Ku, Yokohama, 236-8648, Japan
6 Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsurakoi, Kushiro, 085-0802, Japan
7 Seikai National Fisheries Research Institute, Fisheries Research Agency, 1551-8 Taira-machi, Nagasaki, 851-2213, Japan
8 Graduate School of Environmental Science, Hokkaido University, N10W5, Kita-Ku, Sapporo, 060-0810, Japan
9 Frontier Research Center for Global Change, 3173-25 Showa-machi, Kanazawa-Ku, Yokohama, 236-0001, Japan
10 Japan Science and Technology Agency, Kawaguchi Center Bldg., 4-1-8 Honcho, Kawaguchi 332-0012, Japan

Interannual variations of lower-trophic-level (LTL) ecosystems in the western North Pacific were investigated by a three-dimensional marine ecosystem model, 3D-eNEMURO, in order to clarify dynamical responses of plankton and nutrients to the interanual changes of ocean physical fields, with a focus on mesoscale processes. The 3D-eNEMURO consists of an eddy-resolving ocean general circulation model (C-HOPE) assimilated to satellite SST/SSH by an adjoint scheme (TAMC) and a plankton functional LTL ecosystem model, eNEMURO. The eNEMURO model is an extend version of NEMURO, which is a standard LTL model of PICES; the extension includes the microbial loop and divides compartments of zooplankton and phytoplankton. The 3D-eNEMURO model reproduced well the spatio-temporal variation of macronutrient concentration and zoo- and phytoplankton biomass for major species, in comparison with satellite sea surface chlorophyll by SeaWiFS and *in situ* biogeochemical data (monitored by Fisheries Research Agency along three lines off Japan covering the subarctic, subtropical, subarctic-subtropical transition and coastal regions and the continental shelf region in the East China Sea). The 3D structures of ecosystems in the western North Pacific simulated by the 3D-eNEMURO under realistic driving forces from 1993 to 2006 indicated significant impacts of the spatio-temporal variations of physical fields frequently caused by mesoscale eddies. For example, ecosystems in the regions where the Kuroshio and Kuroshio Extension (KE) flow changed drastically year after year under the influences of mesoscale disturbances interacting with fluctuations of the Kuroshio and KE flow paths. The simulation, moreover, indicated the interannual variation of the plankton biomass is species specific especially in the Kuroshio/KE frontal region.

**28 April, 17:00 (D2-6348)**

## Developing a modeling framework for basin scale models of marine ecosystems

Francisco E. **Werner**[1], Peter H. Wiebe[2] and Jonathan A. Hare[3]

1 Institute of Marine and Coastal Sciences, 71 Dudley Rd., Rutgers University, New Brunswick, NJ, 08901, USA
E-mail: cisco@marine.rutgers.edu
2 Woods Hole Oceanographic Institution, Redfield 2-26, MS#33, Woods Hole, MA, 02543, USA
3 NOAA NMFS Northeast Fisheries Science Center, 28 Tarzwell Dr., Narragansett, RI, 02882, USA

The goal of the North Atlantic BASIN initiative is to understand and predict the impact of climate change on key species of plankton and fish, and associated ecosystem and biogeochemical dynamics at the basin scale, including the surrounding shelves. The modeling elements of BASIN include: (i) integration and interfacing across trophic levels through the development of a suite of models that capture the relevant ecosystem and biogeochemical dynamics on continental shelves and in the ocean basin; (ii) development of a common modeling environment whereby models can be accessed transparently from collaborating institutions using diverse models and ensembles can be developed and analyzed; (iii) establishment of an Ecological Model Intercomparison (ECOMIP) project where the predictions of various ecological models and their relationships to data can be assessed; (iv) a 50-year hindcast and analysis effort using data and data-assimilative hindcasts to study changes that occurred from seasonal to decadal time scales; (v) future modeling scenarios including responses of the ocean with respect to temperature, salinity, currents, *etc*., that drive models of ocean biology and biogeochemistry, and (vi) Observing

System Simulation Experiments (OSSEs) used to optimize the design of field data acquisition across the North Atlantic basin. We discuss these elements as part of a proposed (http://web.pml.ac.uk/globec/structure/multinational/basin/basin.htm) 10-year multidisciplinary program to improve the integrated understanding of the dynamics of the marine ecosystems of the North Atlantic and produce tools to meet the future demands for an ecological strategy for marine ecosystem management, in order to improve ocean management and conservation.

**28 April, 17:15 (D2-6298)**

## A review of the NEMURO.FISH model application to marine ecosystem investigations and its ability to evaluate responses of fish to future climate change

Michio J. **Kishi**[1,2], Shin-ichi Ito[3], Bernard A. Megrey[4], Kenneth A. Rose[5] and Francisco E. Werner[6]

1 Faculty of Fisheries Sciences, Hokkaido University, N10 W5, Sapporo, Hokkaido, 060-0810, Japan
E-mail: kishi@salmon.fish.hokudai.ac.jp
2 Ecosystem Change Research Program, Frontier Research Center for Global Change, 3173-25 Showamachi, Kanazawa-ku, Yokohama City, Kanagawa, 236-0001, Japan
3 Tohoku National Fisheries Research Institute, Fisheries Research Agency, Shinhamacho 3-27-5, Shiogama, Miyagi, 985-0001 Japan
4 National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sandpoint Way NE, Bin C15700, Seattle, WA, 98115-0070, USA
5 Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA, 70803, USA
6 Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ, 08901, USA



The evolution of the NEMURO.FISH (North Pacific Ecosystem Model for Understanding Regional Oceanography, For Including Saury and Herring) family of models to study marine ecosystems is reviewed. NEMURO applications throughout the North Pacific have shown the models to be robust and to be able to reproduce 1, 2 and 3D components of nutrient, carbon cycle and biogeochemical cycles as well as aspects of lower trophic levels ecosystem (phyto- and zooplankton). NEMURO.FISH includes higher trophic levels and can be run uncoupled or coupled to NEMURO. In the uncoupled mode, the growth and weight of an individual fish is computed using plankton densities simulated by NEMURO but with no feedback between fish consumption and plankton mortality. In the coupled mode, the feeding, growth and weight of a representative fish are computed and prey removals due to feeding by fish appear as mortality terms on the prey. The idea of NEMURO.FISH has been applied not only to Pacific saury and herring but also to squid, salmon and the other fish. We review all applied studies including several examples examining fish responses to future climate change. We will discuss the ability of NEMURO.FISH family models to evaluate fish responses to future climate change. Then, we will outline perspectives for future end-to-end modeling efforts that can be used to study marine ecosystem in response to global environmental change.

**28 April, 17:30 (D2-6051)**

## A second generation online tool for exploring oceanographic connectivity

Scott **Condie**, Mark Hepburn, Jim Mansbridge and Phillip England

CSIRO Wealth from Oceans Flagship, GPO Box 1538, Hobart, Tasmania 7001, Australia. E-mail: scott.condie@csiro.au

Fish populations and their associated communities are connected in space and time under the influence of a range of physical and biological processes. Realized patterns of biological connectivity are painstaking to measure or infer, requiring detailed taxonomic, ecological and genetic studies. A complimentary approach is to predict likely dispersal from an understanding of oceanographic currents and the motility of organisms. We describe a new generation of the online tool known as ConnIe (Connectivity Interface). Connie 2.0 uses archived currents from data assimilating oceanographic models and particle tracking techniques to estimate connectivity statistics from user-specified source regions (or to user-specified sink regions) over any period within the archive (presently 1992-2008). A range of biological behaviors can be specified including vertical migration, horizontal swimming, clinging to substrate, and formation of surface slicks. Ongoing developments include larval dependencies (*e.g.* mortality, growth rate) on environmental variables (*e.g.* temperature, salinity, chlorophyll) and integration with other scientific or management tools (*e.g.* ecosystem models, reserve design tools). Options are also being considered for using downscaled climate change scenarios within Connie to explore the implications of changing connectivity patterns. The interface is based on modern Web technologies and uses an interactive Google-maps style display familiar to most users.

**28 April, 17:45 (D2-6131)**

## Climate change induced decadal variations in hydrodynamic conditions in the Estonian coastal waters and their possible influence on fish

Ülo **Suursaar**, Markus Vetemaa and Tiit Kullas

Estonian Marine Institute, University of Tartu, Mäealuse 10a, Tallinn, 12618, Estonia. E-mail: ulo.suursaar@ut.ee

Climate change influences marine ecosystems and fish via various links and mechanisms. Hydrodynamic processes are an important link, but are rarely considered. In Northern Europe, recent climate change strongly manifests as shifts in wind climatology and storminess, as well as increases in temperature. In the semi-enclosed and practically tideless Baltic Sea, climate change induced variations in hydrodynamic conditions include enhanced seasonal signal and contrasting trends in sea level, more higher and frequent storm surges and wave storms, seasonal increases in turbidity, and redistribution of bottom sediment. Changes in thermohaline and oxygen conditions in the shallow spawning and nursery areas are frequently governed by shifts in wind-driven flow patterns, hydrological fronts and upwelling zones. This study is based on meteorological and sea level data from the Estonian weather and tide gauge stations (since 1923), as well as on hydrodynamic modelling experiments with the shallow sea 2D model and wave hindcast for the period 1966-2008. The wave model was calibrated and currents, thermohaline and turbidity were studied on the basis of 18-month measurements with the RDCP. The study includes an analysis of the most important hydrodynamic regime shifts in the Estonian coastal waters and discussion on their possible influences on fish. The latter is based on the historical data of catches, as well as on observation results of littoral species. However, as the data on fish are more strongly influenced by catch (and fishing), the preliminary results, apart from conceptual connections, show just a few and local relationships.

**28 April, 18:00 (D2-6384)**

## The Pacific Decadal Oscillation and marine food webs in the northern California Current: Variations in source waters which feed the California Current may be the mechanism which links climate change with ecosystem response

William T. **Peterson**[1], Hongsheng Bi[2,3], Cheryl A. Morgan[2] and Edmundo Casillas[1]

[1] NOAA-Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR, 97365, USA
E-mail: bill.peterson@noaa.gov

[2] Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, Oregon State University, Newport, OR, 97365, USA

[3] University of Maryland, Chesapeake Biological Laboratory, Solomons, MD, USA

Analysis of hydrographic and zooplankton data collected fortnightly in the coastal upwelling zone off Oregon for the past 14 years and historical observations from the 1970s ands 1980s have shown that variations in sea surface temperature, salinity, copepod biodiversity, species richness and community structure are correlated with the Pacific Decadal Oscillation. When the PDO is negative (as during the 1970s, 1999-2002 and 2008-2009), cold salty waters from the Gulf of Alaska feed the northern California Current (NCC) and transport large, lipid-rich copepods to the shelf waters of the NCC; when the PDO is positive (as in 2003-2007), warm fresher waters from offshore and south feed the NCC and transport small, oceanic lipid-poor copepods to the coast. Thus the basin-scale variations in winds that drive the PDO result in changes in transport that in turn control local food chain structure. These changes in food chain structure correlate with (and predict) salmon returns to the Columbia River. We use altimeter data to show that changes in phase of the PDO are accompanied by changes in source waters which feed the NCC. We argue that to examine how the coastal upwelling ecosystem of the NCC might react to a climate change scenarios, we will need a better understanding of how basin-scale winds and variations in gyre circulation patterns impact source waters which feed the NCC. A combination of ROMS and GCMs should allow examination of future states of the PDO and of regional variations in source waters that feed the NCC.

**28 April, 18:15 (D2-6388)**

## An application of the ethno-oceanographic framework to study global change issues off the South Brazil Bight with remote-sensing data

Maria A. **Gasalla**[1], O. Sato[2] and P.S. Polito[2]

[1] Fisheries Ecosystems Laboratory, Instituto Oceanográfico, University of São Paulo, 055080-900 São Paulo, Brazil
E-mail: mgasalla@usp.br
[2] Satellite Oceanography Laboratory, Instituto Oceanográfico, University of São Paulo, Brazil

An oriented ethno-oceanographic approach was applied to outline hypotheses of change in the ocean off the Southeast Brazil shelf. Based on a fishers' oceanological knowledge-based analysis (FOK), which took into consideration different categories of fishers, new hypotheses on ocean shifts were tested with satellite-based, spatially-explicit time-series. The joint analysis of questionnaires responses from different surveys dealing with fisher's perceptions of change allowed comparison of different fisher's categories and fishing areas. Fishers exploring different ocean zones have perceived some opposite trends of change. The attempt of correlating fishers' perceptions with scientific hypotheses was based on an observational data search procedure. *In-situ* evidences of change in sea temperature, winds intensity, rainfall, and correlation with climatic indexes were obtained. Further explanations of change were derived from available knowledge on the South Atlantic oceanography. A user-based process appeared to contribute especially in data-poor ecosystems. A collaborative approach can be used to establish interdisciplinary dialogue in climate change studies and can be followed by available modern ocean science tools.

# D2 Posters

### D2-6093 (*Cancelled*)

## Climate change and the ecosystem response in the South China Sea: Observations and numerical investigations

Hui **Wang**[1], Guimei Liu[1], Fei Chai[2], Xingyu Song[3] and Shan Gao[1]

[1] National Marine Environmental Forecasting Center, Beijing, 100081, PR China. E-mail: wangh@nmefc.gov.cn
[2] University of Maine, School of Marine Sciences, 5706 Aubert Hall, Orono, ME, 04469, USA
[3] South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou, 510301, PR China

Climate change may induce changes in the structure and functioning of marine plankton and hence on fish and fisheries. The responses of ecosystems to perturbations are difficult to predict because they result from complex interactions among the ecosystem components. In this presentation, the changes of primary productivity associated with pentad outgoing longwave radiation (OLR), East Asia Monsoon index, pentad rainfall, and Sea Level Anomaly (SLA) are analyzed based on the meteorological data, observational data and satellite data in the SCS. A Pacific basin-wide physical-biogeochemical model is developed and used to investigate physical variations and ecosystem responses. The Pacific basin-wide circulation model, based on the Regional Ocean Model Systems (ROMS), is forced with daily air-sea fluxes derived from the National Centers for Environmental Prediction (NCEP) reanalysis between 1990 and 2004. The biogeochemical processes consist of multiple nutrients and plankton functional groups and detailed carbon cycle dynamics. The ROMS-CoSINE model is capable of reproducing many observed features and their variability in the SCS. The regional difference of Chl-*a*, in relation to local environmental conditions, is also investigated. The monsoon-driven upwelling and meso-scale eddies likely determine the Chl-*a* differences locally. The results and analysis showed that the Chl-*a* in the SCS respond to the climatic variability.

### D2-6104

## Variability of the biotic material flow divergence patterns of the Azores

Aleksey V. **Koldunov**

Laboratory of Regional Oceanography, St. Petersburg State University, 33-35 Line of Vasilievsky Island, St. Petersburg, 199178, Russia
E-mail: koldunovaleksey@gmail.com

This study uses an original method for detecting biotic fronts. Contrary to the traditional consideration of frontal zone as an area of maximal gradients, our approach applies a simple theory: biotic fronts appear in convergence areas. From this simple idea, a biotic frontal zone may be treated as a locality where the substance flow divergence is less than zero, *i.e.* convergence zone. Accordingly, a biotic front will be the line of maximal convergence. Fields of primary production and ocean currents in the vicinity of the Azores are used to estimate fields of the substance flow divergence and to discover biotic frontal zones. The first clearly expressed front at north-west off the Azores coincides with a zone of higher mean values of primary production and of very rich blooms, as well with an area where advection and turbulent diffusion are most developed. The second frontal zone lies to the east and south off the Azores. The southern end of front coincides with area of the earliest bloom in January-February. Comparing the obtained results and the geostrophic current fields calculated by AVISO data shows that the north-western frontal zone is confined to an area occupied by southern branch of the North Atlantic Current. Weak divergences at 40-41°N and 28-30°W correspond to a certain "rupture" in North Atlantic Current's Southern Branch, where current speed decreases from 10 to 6 cm/s, but beyond the front it again rises up to 9 cm/s.

**D2-6177**

## Potential impact of global warming on North Pacific spring blooms projected by an eddy-permitting 3-D ocean ecosystem model

Taketo **Hashioka**[1,2], Takashi T. Sakamoto[1], Hiroshi Sumata[3], Takeshi Okunishi[4], Masahito Shigemitsu[3], Maki N. Aita[1], Naoki Yoshie[5], Naosuke Okada[3], Akio Ishida[1,2] and Yasuhiro Yamanaka[1,2,3]

1 Japan Agency for Marine-Earth Science and Technology, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, Kanagawa, 236-0001, Japan E-mail: hashioka@jamstec.go.jp
2 Core Research for Evolutional Science and Technology (CREST) / Japan Science and Technology Agency (JST), 4-1-8 Honcho, Kawaguchi-shi, Japan
3 Graduate School of Environmental Earth Science, Hokkaido University, N10W5 Kita-ku, Sapporo, Hokkaido, 060-0810, Japan
4 National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa, 236-8648, Japan
5 Center for Marine Environmental Studies, Ehime University, 2-5 Bunkyo-cho, Matsuyama, Ehime, 790-8577, Japan

We developed an eddy-permitting version (*i.e.*, horizontal grid-spacing of 0.28° (zonally) × 0.19° (meridionally)) of our 3-D ecosystem model, COCO-NEMURO (the CCSR Ocean Component Model coupled with the North Pacific Ecosystem Model Used for Regional Oceanography), and applied it to the surface 1500 m in the western North Pacific (about 110°E-180°, 10-60°N) with an offline calculation method. Using this model with a projected physical environment from a high-resolution climate model (the Model for Interdisciplinary Research on Climate, MIROC, version 3.2), we explored the potential impact of global warming on spring blooms in the western North Pacific. We focused on statistically significant signals compared with natural variability. Considering $2xCO_2$ conditions, maximum biomass during the spring bloom is found to occur 10 to 20 days earlier due to strengthened stratification. In the subarctic region, the bloom decreases in magnitude relative to pre-industrial simulation. However, in the northern part of the Kuroshio extension region where photosynthesis is not strongly limited by nutrients, the maximum biomass increases by 20 to 40% associated with rising temperatures, even though the annually averaged biomass slightly decreases. Our results reveal that even if global warming weakly affects annually averaged quantities, it could strongly affect certain species and biogeochemical processes which depend on seasonal events such as blooms. We will also present the preliminarily results of our new ecosystem model which explicitly represents iron cycles.

**D2-6192**

## One dimensional ecosystem model in the northern Japan Sea based on an operational ocean forecast system

Tatsuro **Watanabe**[1], Katsumi Takayama[1], Hideyuki Kawamura[2] and Iori Tanaka[3]

1 Japan Sea National Fisheries Research Institute, Fisheries Research Agency, Niigata, 951-8121, Japan. E-mail: tatsuro@fra.affrc.go.jp
2 Research Group for Environmental Science, Nuclear Science and Engineering Directorate, Japan Atomic Energy Agency, Tokai-mura, 319-1195, Japan
3 Hokkaido Central Fisheries Experiment Station, Yoichi, 946-8555, Japan

Based on an operational ocean forecast system for the Japan Sea, a one dimension lower trophic ecosystem model called the NEMURO (Kishi *et al.*, 2007) was applied for understanding seasonal and vertical variations of the primary production in the northern Japan Sea. The daily mean of the vertical structure of the temperature and the vertical diffusion coefficient in the area at latitude 41-43ºN and longitude 137-139ºE, calculated from 2003 to 2008, was provided to the ecosystem model from the ocean forecast system including data assimilation of SST, SSH and CTD. As a result, the ecosystem model showed realistic vertical distributions and their seasonal variations of nitrate, phytoplankton and zooplankton. Though there was few available observation data for the validation in the northern Japan Sea, the long-term bimonthly observations, which were carried by the Hokkaido Central Fisheries Experiment Station, were used for the validation. In particular, on the distribution of the phytoplankton, our ecosystem model well reproduced the typical feature of the seasonal variations in the northern Japan Sea. The spring bloom occurred with approximately $1.5x10^{-6}$ molN/l in early April from the surface to the depth of 50m. Subsequently the subsurface maximum formed at the depth of 40m and it became deeper slowly to the depth of 60m until fall. In late November, the weak fall bloom occurred in the surface layer.

**D2-6256**

## Dynamics of lower-trophic-level ecosystems in the western North Pacific simulated by a high resolution 3D ecosystem model

Naoki **Yoshie**[1], Kosei Komatsu[2], Shin-ichi Ito[3], Takahiko Kameda[4], Tsuneo Ono[5], Kiyotaka Hidaka[4], Toru Hasegawa[6], Akira Kuwata[3], Miwa Nakamachi[3], Yuji Okazaki[3], Takeshi Okunishi[4], Kazuaki Tadokoro[3], Hiroaki Saito[3] and Yasuhiro Yamanaka[7,8,9]

1 Center for Marine Environmental Studies, Ehime University, 2-5 Bunkyo-cho, Matsuyama, 790-8577, Japan
E-mail: nyoshie@sci.ehime-u.ac.jp
2 Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan
3 Tohoku National Fisheries Research Institute, Fisheries Research Agency, 3-27-5 Shinhama-cho, Shiogama, 985-0001, Japan
4 National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa-ku, Yokohama, 236-8648, Japan
5 Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsurakoi, Kushiro, 085-0802, Japan
6 Seikai National Fisheries Research Institute, Fisheries Research Agency, 1551-8 Taira-machi, Nagasaki, 851-2213, Japan
7 Graduate School of Environmental Science, Hokkaido University, N10W5, Kita-ku, Sapporo, 060-0810, Japan
8 Frontier Research Center for Global Change, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, 236-0001, Japan
9 Japan Science and Technology Agency, Kawaguchi Center Bldg., 4-1-8 Honcho, Kawaguchi, 332-0012, Japan

Spatiotemporal variations of the lower-trophic-level marine ecosystem in the western North Pacific were investigated by a marine ecosystem model. The goal of this modeling was to understanding of mechanisms and developing prediction skills of ecosystem responses to climate changes. We developed a plankton functional types model eNEMURO, which was an extended version of NEMURO (a standard lower-trophic-level marine ecosystem model of PICES) by introducing the microbial food web and dividing diatoms to two compartments according to temperature dependency. eNEMURO was coupled with an eddy-resolving ocean general circulation model (C-HOPE, horizontal resolution: 1/16º) assimilated to satellite altimetry and sea-surface-temperature by TAMC method. We applied 3D eNEMURO to the western North Pacific from 1998 to 2006, and compared the model outputs with biogeochemical and ecological data observed at three seasonally repeated monitoring lines of Fisheries Research Agency Japan (A-line including the subarctic region [Oyashio region] and subarctic-subtropical transition region [Oyashio-Kuroshio transition region], O-line including the subtropical region across the Kuroshio current, and CK-line including the continental shelf region in the East China Sea). The biological parameters of eNEMURO were tuned for reproducing plankton and nutrient dynamics in those quite different ecological regions using 0D (box) eNEMURO. The results of 3D eNEMURO with new tuned parameters showed high performance to reproduce the distributions and variabilities of the plankton biomasses and nutrient concentrations with eddy to synoptic spatial and week to interannual time scales. We will continue to carry out further investigation to elucidate the mechanism of lower-trophic-level ecosystem responses to the climate forcings.

**D2-6277**

## The impact of density-dependent processes on geographical distribution of Japanese sardine (*Sardinops melanostictus*)

Takeshi **Okunishi**[1], Shin-ichi Ito[2], Naoki Yoshie[3], Taketo Hashioka[4], Hiroshi Sumata[5] and Yasuhiro Yamanaka[4,5]

1 National Research Institute of Fisheries Science, Fisheries Research Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa, 236-8648, Japan. E-mail: okunishi@affrc.go.jp
2 Tohoku National Fisheries Research Institute, Fisheries Research Agency, 3-27-5 Shinhama-cho, Shiogama, Miyagi, 985-0001, Japan
3 Center for Marine Environmental Studies, Ehime University, Japan
4 Japan Agency for Marine-Earth Science and Technology, Yokohama, 236-0001, Japan
5 Graduate School of Environmental Earth Science, Hokkaido University, N10W5, Kita-ku, Sapporo, 060-0810, Japan

Population fluctuations of small pelagic fishes, such as sardine and anchovy, are related to climate change. Density-dependent effects in small pelagic fishes often affect their growth and distribution and the lower trophic ecosystem. To represent the density-dependent effects as two-way interaction between the Japanese sardine and the lower trophic ecosystem, we developed a multi-trophic level ecosystem model including Japanese sardine by coupling physical, biochemical-plankton and fish models. The fish model used individual-based modeling (IBM) techniques. Lagrangian particles (fish) of the IBM represent members of the sardine population, and the affects phytoplankton and zooplankton densities through feeding can be tracked. In the model, fish movement is assumed to be controlled by feeding and spawning migrations with passive transport by ocean currents. Feeding migration is assumed to be governed by searching for local optimal habitats of fish. The model was implemented under scenarios of high and low standing stocks of Japanese sardine, and results were compared between scenarios with

regard to both growth and distribution. An increase in the area occupied by adult sardine at the high stocks was found. This result appears to provide support for the hypothesis of density-dependent habitat selection. Age 0 fish showed slower growth rate under the high stocks in summer because forage density decreases from high grazing pressures of adult sardine. The effect of density dependence among lower trophic levels and fish seems to be one of the most important factors which determine the geographical distribution of adult sardine and growth of young sardine.

**D2-6322**

## Interannual to decadal modulations of high frequency eddies in the Kuroshio-Oyashio confluence zone in a high-resolution CGCM with ocean data assimilation

Hiroaki **Tatebe**[1], Masayoshi Ishii[1,2], Masahide Kimoto[3], Takashi T. Sakamoto[1], Yoshiki Komuro[1] and Takashi Mochizuki[1]

1 Japan Agency for Marine-Earth Science and Technology, 3173-25 Showa-machi, Kanazawa-ku, Yokohama, 236-0001, Japan
E-mail: tatebe@jamstec.go.jp
2 Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki, 305-0002, Japan
3 Center for Climate System Research, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8568, Japan



For predicting a near-term climate up to year 2030, decadal hindcast/forecast experiments are in progress using a System for Prediction and Assimilation by MIROC (SPAM). The global coupled atmosphere-ocean model MIROC has an eddy-permitting oceanic component with 1/4° x 1/6° horizontal resolution and an atmospheric component with horizontal resolution of T213 spectral truncation (about 60 km). For initialization, historical ocean subsurface data are assimilated into the ocean model. Eddies in the model are filtered out in calculating analysis increment in the assimilation procedures. This approach is used to assimilate only basin-scale and long-term variations resolved in the observational data and to generate high-frequency eddies physically in response to background currents and hydrographic structures. In the preliminary experiment, where an older version of MIROC for IPCC AR4 is used and the data assimilation is started at 1990, the interannual to decadal modulations of high frequency eddy activities observed in the Kuroshio-Oyashio confluence zone (KO zone) are reproduced. The eddies in the KO zone are known to play an important role in transporting nutrient, large zooplanktons, *etc.* in the subarctic North Pacific to the subtropics. The reproducibility and maybe predictability of the long-term modulations of the eddy activities in the KO zone contribute to progress in forecasting changes in fisheries and catches of various pelagic fishes, such as Japanese sardines and Pacific sauries.

**D2-6337**

## MIROC4.0 – A high-resolution AOGCM for the near-term climate prediction

Takashi T. **Sakamoto**[1], Yoshiki Komuro[1], Masayoshi Ishii[2,1], Hiroaki Tatebe[1], Akira Hasegawa[3], Hideo Shiogama[3], Takahiro Toyoda[1], Masato Mori[4], Seita Emori[3,1,4], Hiroyasu Hasumi[4] and Masahide Kimoto[4]

1 Japan Agency for Marine-Earth Science and Technology, 3173-25 Kanazawa-ku, Yokohama, Kanagawa, 236-0001, Japan
E-mail: teng@jamstec.go.jp
2 Meteorological Research Institute, Japan Meteorological Agency, 1-1 Nagamine, Tsukuba, Ibaraki, 305-0052, Japan
3 National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki, 305-8506, Japan
4 Center for Climate System Research, The University of Tokyo, Kashiwa, Chiba, Japan

Preliminary results are presented from the general circulation climate model, Model for Interdisciplinary Research on Climate (MIROC) version 4.0. The model was developed by the Center for Climate System Research (CCSR), the University of Tokyo; National Institute for Environmental Studies (NIES); and Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The atmospheric component is T213 spectrum model (~60 km mesh), and the ocean component is an eddy-permitting ocean general circulation model whose horizontal resolution is 0.28125° zonally and 0.1875° meridionally. Using this model, 50 years spin-up and 70 years control experiments were conducted under the condition of year 1950 without flux adjustment. Biases in the SST field, typically warm bias in high-latitudes and cold bias in low and mid-latitudes, are reduced in MIROC4.0, especially in the Northern Hemisphere. There are still drifts in the globally averaged ocean temperature and salinity, but these drifts are smaller than the previous version of the MIROC (MIROC3.2_hires). Simulated ENSO signal and its related SST, precipitation, SLP in the model are improved from the MIROC3.2_hires. The spatial distribution of PDO is also improved. We will conduct near-term climate prediction experiments for the coming decades to contribute to CMIP5 and IPCC AR5.

# GP General Poster Session

**GP-5783**

## Kuroshio System – The quasi-cyclic dynamics and the bifurcation from the source to the Shatskikiy hills

Vladimir B. Darnitskiy and Maxim A. **Ishchenko**

V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS, 43 Baltiyskaya St., Vladivostok, Primorsky Kray, 690041, Russia
E-mail: maksim@poi.dvo

An adequate assessment of the ocean's role in the formation of weather and short-period oscillations of the Earth's climate requires knowledge of current ocean conditions and their variability. Knowledge of these processes is needed to develop sustainable strategies for using biological resources of the oceans. The purpose of this communication is an attempt to assess the variability of the Kuroshio main stream at different locations ranging from the origins of the Kuroshio on Taiwan, to regions along the Ryukyu ridge and Archipelago of Japan and partly in the North-West Pacific from Japan to upland Shatskikiy rise. The data used consisted of an information contained in the TINRO, FERHRI, and POI FEB RAS databases and the archive of Levitus (2006). The amplitudes of variability of the thermohaline parameters were calculated in 5° squares to a depth of 600 meters as described previously by Darnitsky and Ishchenko (2008). The area of bifurcation of the main Kuroshio jet was analyzed from the source to the Shatskikiy hills. In Izu Ridge and the area of jet separation from the coast of Japan near the cluster of Kashima seamounts we studied the influence of bottom topography on the inter-annual dynamics of the thermohaline parameters and the amplitude of the intermediate layer of salinity minimum (500 m horizon). A nonlinear approximation of the series (1960-2000 years) showed medium-and long-term trends in temperature amplitudes variability in the various sectors of the Kuroshio system. Interdecadal cycles near the southern and eastern coast of Japan were studied previously (Darnitsky, Ishchenko, 2008). Satellite imagery was used fragmentarily, as well as information on the trajectories of Argo buoys. Internal dynamics of the West Subtropical Circulation, as is done in previous work (Darnitsky, Pokudov, 1995) will also be addressed.



**GP-6084**

## Contrasting pattern of genetic differentiation between two Antarctic Channichthyidae fish species at the West Antarctic Peninsula

Chiara **Papetti**[1], Mario La Mesa[2], Jennifer Rock[3], Esteban Barrera-Oro[4,5], Tomaso Patarnello[1,6] and Lorenzo Zane[1]

1 Department of Biology, University of Padova - via G. Colombo, 3 – 35121, Padova, Italy. E-mail: chiara.papetti@unipd.it
2 Institute of Marine Science (CNR-ISMAR), Marine Fishery Section-Largo Fiera della Pesca, 1, Ancona (An), 60125, Italy
3 Molecular Ecology and Fisheries Genetics Laboratory, School of Biological Sciences, University of Wales, Bangor, LL57 2UW, UK
4 Instituto Antártico Argentino, Cerrito 1248, Buenos Aires, A1010AAZ, Argentina
5 Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", División Ictiología, Angel Gallardo 470, Buenos Aires, CI405DJR, Argentina
6 Department of Public Health, Comparative Pathology and Veterinary Hygiene, University of Padova - viale dell'Università 16, Agripolis, Legnaro (PD), 35020, Italy

A comparative population genetics study was conducted on two Antarctic Channichthyidae fish species, *Chionodraco rastrospinosus* and *Chaenocephalus aceratus*, which shows similar ecology and partially overlapping distribution ranges in the West Antarctic Peninsula (WAP), therefore experiencing a common water circulation pattern dominated by the Antarctic Circumpolar Current from west to east. The two species exhibit a strikingly different pattern in their population genetics in samples collected from comparable sites. Whereas *C. rastrospinosus* appears to be panmictic, *C. aceratus* showed a clear genetic differentiation among samples. Our findings suggest that, in addition to ocean circulation and larval dispersal, other major factors might be driving connectivity. The contrasting genetic pattern found could be attributable to differences in behavior, subtle differences in the dispersion potential of adults, and to buoyancy features. Moreover, the differences in genetic diversity could be caused, in part, by variability in patterns of water circulation at small spatio-temporal scales, which might be further enhanced by global warming. Large-scale global warming events may influence ocean and marine fauna of the WAP continental shelf by reducing suitable habitats and changing ecological dynamics. Long-term effects might include strong inter-annual variability in the recruitment and growth of both pelagic and

benthic organisms. While organisms are adapted to historical levels of such variability, they might not be able to cope with a significant increase in the frequency of years of low recruitment or slow growth, likely resulting in an alarming loss of genetic variability and decreases in effective and absolute population sizes.

**GP-6134**

## The influence of seawater temperature on sandeel stock in Ise Bay

Minoru **Tomiyama**[1] and Teruhisa Komatsu[2]

[1] Department of Agriculture, Forestry and Fisheries, Aichi Prefectural Office, Nagoya, Aichi, 460-8501, Japan
E-mail: minoru_tomiyama@pref.aichi.lg.jp
[2] Ocean Research Institute, The University Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo, 164-8639, Japan

Japanese sandeel (*Ammodytes personatus*) is one of the most important bio-resources in Ise Bay (central Honshu Island, Japan) Most abundant in early spring; the Japanese sandeel plays a dominant ecological role in the Isle Bay fish fauna year-round. This study examined the influence of water temperature on sandeel population in Ise Bay by analyzing the relationship between water temperature and year class strength of the sandeel estimated by De Lury's method in Ise Bay from 1995 to 2001. There was a negative correlation between water temperature experienced in January, just a few weeks after the hatching of sandeel eggs, and the year class strength of sandeel in Isle Bay (higher water temperature in early spring was related to weaker year strength of sandeel). Growth of Japanese sandeel (23.7 - 38.4 mm body length) was investigated based on growth trajectories of individual larvae recorded in otolith rings. Results showed that high temperature was related to both a high growth rate and a low reproductive (Offspring/Spawner) rate. Since sandeel bury themselves during high water temperature in summer to conserve energy, the start of this aestivation period becomes earlier with increasing seawater temperature. It is concluded that global warming will have negative effects on the sandeel population in Ise Bay, a region that is close to the southern limit of the latitudinal distribution of this species in northern hemisphere.

**GP-6193**

## Climate change and fisheries in Chile

Eleuterio **Yáñez** and María Angela Barbieri

Escuela de Ciencias del Mar, Facultad de Recursos Naturales, Pontificia Universidad Católica de Valparaíso, P.O. Box 1020, Valparaíso, Chile. E-mail: eyanez@ucv.cl

The possible effects of climate change on the Chilean marine ecosystems are considered. Efforts to establish relationships between the abundance of exploited species, fishing effort and environmental variables are also suggested. Finally, conceptual models for an ecosystem management of the fisheries, as well as indications on the necessity to evaluate the fisheries behaviour, given the climate change scenario, are suggested.

**GP-6204**

## Chlorophyll *a* concentration dynamics due climate change and its possible impact on pelagic fishes at Java and Bali, Indonesia: Case study in 2006

Aida **Sartimbul**[1], Hideaki Nakata[2] and Erfan Rohadi[3]

[1] Faculty of Fisheries and Marine Sciences; Center of Environmental Studies, University of Brawijaya, Jalan Veteran, Malang 65145, Indonesia. E-mail: aida@brawijaya.ac.id, aidasartimbul@yahoo.com
[2] Faculty of Fisheries, Nagasaki University, 1-14 Bunkyo-machi, Nagasaki, 852-8521, Japan
[3] Department of Management Informatics, State Polytechnic of Malang, Jalan Sukarno Hatta, Malang, 65145, Indonesia

Chlorophyll *a* concentration dynamics in 2003 to 2008 were studied at Java (South of Java Sea) and Bali (Bali Strait and Coast of Bali) using Aqua-Modis satellite data. Together with Catch per Unit Effort (CpUE) of some pelagic fishes, Sea Surface Temperature (SST) and climate change parameters (Niño 3.4 and IOD), their possible relationship were analyzed. The result show that the recent warming is not significantly impact on increasing SST but more intensively occurring unpredictable phenomena such as El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). The chlorophyll *a* anomalies significantly increase above normal for three areas at Java

and Bali coincide with upwelling process due to the drop of SST during ENSO and IOD in 2006. Significantly increase of chlorophyll *a* in 2006 has led the productivity of some pelagic fishes at three areas of study. There is unlagged respond between chlorophyll *a* and SST, however lagged response between chlorophyll *a* and CpUE of some pelagic fishes as follows: four-months lagged between chlorophyll *a* and CpUE *Sardinella lemuru* at Bali Strait, five-months lagged between chlorophyll *a* and CpUE *Sardinella lemuru* at the coast of Bali, and seven-months lagged between chlorophyll *a* and CpUE *Thunnus albacores* at South of Java Sea. Increasing chlorophyll *a* is followed by increasing catch of *Sardinella lemuru* four and five months later at Bali Strait and the coast of Bali respectively, while *Thunnus albacores* seven-months later at South of Java Sea.

**GP-6205**

## The implication of oceanographic and meteorological factors on algae blooming events and possible impact on the *Sardinella lemuru* fishery along the coast of Bali, Indonesia

Oky Rosita Tanjung, Aida **Sartimbul** and Anthon Efani

Faculty of Fisheries and Marine Science, Universitas Brawijaya, Jalan Veteran, Malang, 65145, Indonesia
E-mail: aida@brawijaya.ac.id; aidasartimbul@yahoo.com

A mass mortality event on pelagic species occurs almost every four years along the coast of Bali. This event has been triggered by algae blooms due to climate change during recent decades. Therefore, the aim of this study is to understand the implication of oceanographic and meteorological factors on algae blooms along the coast of Bali. Time series (2003-2008) of chlorophyll *a* concentration, sea surface temperature (SST), Indian Ocean Dipole (IOD), precipitation, wind speed, and air pressure were analyzed together using multivariate analysis such as the Principal Component Analysis (PCA) after experienced anomaly analysis. The results show that the dominant factors affecting blooming algae along the coast of Bali are ordered as follows: chlorophyll *a*, SST, IOD, precipitation, wind speed and air pressure. There is a lagged response between chlorophyll *a* and Catch per Unit Effort (CpUE) of *Sardinella lemuru* where increasing chlorophyll *a* is followed by increasing CpUE *Sardinella lemuru* five months later. There is a significant relationship between chlorophyll *a* and the five-month lagged CpUE *Sardinella lemuru* anomalies, as shown by $r = 0.535$ with $p < 0.05$.



**GP-6206**

## Biological aspects and population dynamics of mud crab (*Scylla serrata*) in the mangrove area of Curah Sawo, Probolinggo, Indonesia

Sary Rahmawati, Aida **Sartimbul** and Daduk Setyohadi

Faculty of Fisheries and Marine Science, Universitas Brawijaya, Jalan Veteran, Malang, 65145, Indonesia
E-mail: aida@brawijaya.ac.id; aidasartimbul@yahoo.com

A study on the biological aspects and population dynamics of mud crab *(Scylla serrata)* was conducted from May to September 2009 in the mangrove area of Curah Sawo, Probolinggo, Indonesia. The aim of this research is to estimate the biological and growth parameters, recruitment patterns, mortality rates, and exploitation status of mud crab in this area. A total of 287 mud crabs were captured in 5 sample taken with. The crabs had a negative allometric correlation of length and weight with a growth rate coeficient of 1.3 per year. This crab is assumed to spawn in June and July, as the highest percentage of maturity was in June, while in August there were crabs that were in spent condition. Length of the mud crab in the first capture (Lc) was longer than the length in the first gonad mature (Lm). On the other hand, natural maturity rates of the mud crab are higher than fishing mortality. Using the FISAT (Fish Stock Assessment Tools) program, it can be assumed that the status of the mud crab fishery, based on its exploitation rate value (E = 0.15), is still underfished, and its exploitation level, based on Yield per Recruit, is only about 1.2%.

**GP-6326**

## Biological studies of the oval squid *Sepioteuthis lessoniana* population in northern Taiwan

Chia-Hui **Wang** and Hui-Lun Chen

Earth Dynamic System Research Center, National Cheng Kung University, 1 University Rd., Tainan 704, Taiwan, ROC
E-mail: chwang@mail.ncku.edu.tw

The present study aims to describe the biology of the oval squid (*Sepioteuthis lessoniana* Lesson, 1830) around the northern Taiwan coastal area. Samples of *S. lessoniana* were collected monthly from June 2007 to January 2008. The morphological parameters and maturity stages were examined and statoliths were extracted for daily age and growth analyses. From 226 specimens of *S. lessoniana* collected, there were 50.5 % females and 49.6 %, giving a sex ratio of 1:1.01 (F: M). The dorsal mantle lengths of both sexes varied between 60-263 mm and the total body weight ranged between 27–1337 g. Mature males had a larger size range than females. The frequency distributions of maturity stages from different months showed that males are mature during most of the sampling months, while females showed higher maturities in late spring and winter months. The statolith increment numbers for females and males ranged from 81-229 and 83-207 days respectively, with females having a wider range of ages. The hatching date of each squid was back calculated from the sampling date and the number of statolith increments with the results showing that hatching occurred throughout most of the year for the *S. lessoniana* population in north Taiwan, with a peak season in spring. Chemical compositions of statoliths were also analyzed in order to trace their larval origin.

**GP-6327**

## Forecasting models in the recruitment of Japanese sardine, *Sardinops melanostictus*, in the northwestern Pacific, incorporating environmental conditions and evaluations of management effects

Kazumi **Sakuramoto**[1], Satomi Shimoyama[2] and Naoki Suzuki[1]

[1] Tokyo University of Marine Science and Technology, Konan, Minato, Tokyo, 108-8477, Japan. E-mail: sakurak@kaiyodai.ac.jp
[2] Survey Research Center Co. Ltd., Nishi-Nippori, Arakawa, Tokyo, 116-8581, Japan

We investigated the relationships between environmental conditions and fluctuations in the recruitment of Japanese sardine, *Sardinops melanostictus*, in the northwestern Pacific. Stock–recruitment relationships were estimated based on Ricker, Beverton–Holt, power, linear, and proportional models. The error terms of the stock–recruitment relationship were assumed to follow normal or log-normal distributions. We calculated the correlation coefficients between environmental factors and residuals by subtracting estimated values from those observed. The correlation coefficients were calculated using two different datasets: the entire dataset (1976–2004) and the entire dataset minus data from 1988–1991, when crucial failures in recruitment occurred. Analysis of the full dataset yielded a greater number of environmental factors with significant correlation coefficients than did analysis of the partial dataset. We then constructed recruitment forecasting models incorporating environmental factors. Using these models, we evaluated the effect of fishing for various fishing intensities. The results indicate that the crucial failures in recruitment during 1988–1991 can be explained by environmental factors (*e.g.*, Arctic Oscillation, Pacific Decadal Oscillation, sea surface temperature of the southern area of the Kuroshio Extension), especially those factors that occurred during the spawning season, which are critical in terms of population fluctuations. The recruitment forecasting models performed well in estimating the observed recruitment. After 1991, when recruitment levels were very low, it became difficult for recruitment to recover to the levels of the 1980s; however, if the fishing intensity had exceeded the present-day revel, recruitment would have suffered even greater declines.

**GP-6332**

## Effect of measurement errors on model selection in analyses of the stock–recruitment relationship

Naoki **Suzuki** and Kazumi Sakuramoto

Tokyo University of Marine Science and Technology, Konan, 4-5-7 Minato, Tokyo 108-8477, Japan. E-mail: naoki@kaiyodai.ac.jp

In the case that measurement errors are incorporated in recruitment *R* and spawning stock biomass *SSB*, we examined which model performs best in the proportional, linear, Ricker and Beverton–Holt (B-H) models for predicting the stock–recruitment relationship. We employed error terms normally or log-normally distributed with 20% or 60% of coefficient of variation *CV*. On the assumption that the Ricker, B–H or proportional models were the true stock–recruitment relationship, Monte Carlo simulations were conducted 1000 times for four models. The optimal model was selected with *c-AIC* (finite correction of Akaike information criterion). Reproductive success *RPS* (*R*/*SSB*) was tested by incorporating measurement errors in *SSB* and *R* when true *RPS* was constant. In the case that the Ricker or B–H model was selected as the optimum model, the probability that the model was erroneously selected was 53% for measurement errors log-normally distributed with 60% of *CV*. In the case that the proportional model was selected as the optimum model, however, this probability was 0%. Although *RPS* was assumed to be constant, the simulation trial frequency that the slope of *RPS* to *SSB* was significantly estimated was 70–99% under the condition that measurement error of *SSB* was high (*CV* = 60%). This study indicates a high probability that the estimated Ricker or B–H model was erroneously selected in the case that measurement errors were incorporated in *R* and *SSB*. Furthermore, the possibility would exist that *RPS* was under-estimated for high *SSB* and over-estimated for low *SSB*.

**GP-6369**

## Fishery-induced changes on the reproductive cycle of two small pelagic fish off central Chile

Luis A. **Cubillos**[1], Leonardo R. Castro[2] and Gabriel Claramunt[3]

[1] Doctorado en Oceanografía, Universidad de Concepción, Concepción, Chile. E-mail: lucubillos@udec.cl
[2] Laboratorio de Oceanografía Pesquera y Ecología Larval, Universidad de Concepción, Concepción, Chile
[3] Departamento de Ciencias del Mar, Universidad Arturo Prat, Iquique

Two small pelagic fishes, the common sardine, *Strangomera bentincki*, and the anchovy, *Engraulis ringens*, are commercially important fish resources for artisanal and industrial fishermen operating off central Chile (33°S-40°S). The reproductive strategy appears to be similar for both the species, and because they are similar in size, they tend to aggregate in mixed schools, and coexist in the same reproductive and feeding coastal habitat. However, important demographic effects on the reproductive cycle have been described. Larger females of common sardine (repeat spawners) have a reproductive peak earlier in the season than younger first time spawners, while larger anchovy have a delay in the reproductive peak compared with first-time spawners. In this paper fishery-induced demographic effects on the seasonal reproductive cycle are analyzed. The fishing effort is intense and concentrated on the juvenile fraction of the stock, and is thus dependent on the annual recruitment pulse. The fishery tends to remove the fast-growing fish, and the size/age structure becomes truncated. For the sardine it is possible that the fishery tends to select slower growing fish early in the season, thus altering the reproductive cycle. The anchovy appears to be less impacted by heavy fishing pressure than the sardine, because the duration and intensity of spawning is greater. The consequences of the fishery-induced changes are observed directly in the gonadosomatic index and in the spatial pattern of spawning. These changes may enhance the sensitivity of the common sardine population to climatic variability.

**GP-6410**

## Measurements of $NO_3$ saturation in the Japan Sea by *in situ* and hydrochemical methods

Dmitry D. **Kaplunenko**, Vyacheslav B. Lobanov, Alexander Yu. Lazaryuk, Pavel Ya. Tishchenko and Vladimir A. Zvalinsky

V.I. Il'ichev Pacific Oceanological Institute (POI), FEBRAS, 43 Baltiyskaya St., Vladivostok, 690041, Russia. E-mail: dimkap@poi.dvo.ru

The continuous measurement of seawater-dissolved components, such a nutrients and organic materials, is an important task for ecosystem management. In this matter, the In Situ Ultraviolet Spectrophotometer (ISUS) designed by Monterey Bay Aquarium Research Institute (MBARI) and manufactured by Satlantic (MBARI ISUS) is a unique device which allows one to collect *in situ* data on the concentration of components (nitrates, nitrites, bisulfides, bromides, iodides, thiosulfate and other organic material which can absorb ultraviolet light) dissolved in the seawater. The MBARI ISUS instrument model V3 has been successfully used for the detection of nitrate concentration in the Japan Sea during the cruise of the R/V *Akademik M.A. Lavrentyev* from July 3-20, 2009. One of the goals of this cruise was to repeat the extensive oceanographic survey of the sea implemented in the summer of 1999 during the cruises of the R/V *Roger Revelle* and R/V *Professor Khromov* to compare results and analyze the changes in water properties over a ten-year period. The data obtained by MBARI ISUS profiles of $NO_3$ were compared with the data from bottle water samples treated by chemical analysis during the surveys of 1999 and 2009. These profiles show good correlation with the chemical analysis data of the subsurface layer. They had some differences with the accurate $NO_3$ detection for both 1999 and 2009 in the upper layers, but matched very well for deep layers, below 200 m. In general, results of the 2009 cruise showed that using the MBARI-ISUS can provide a detailed structure of the $NO_3$ vertical profile which is impossible to see using the bottle data.

**GP-6412 (*Cancelled*)**

## Response of zooplankton and phytoplankton to climate change in China

Jingfeng **Fan**, Gengchen Han, Chuanlin Huo, Xinzhen Lin and Chunjiang Guan

National Marine Environmental Monitoring Center, Dalian, 116023, PR China. E-mail: jffan@nmemc.gov.cn

We conducted a pilot ecological monitoring project to determine the response of marine organisms to climate change with zooplankton and phytoplankton as the main monitoring targets. Thaliaceans, *Creseis acicula, Sagitta enflata, Temora stylifera* and other tropical warm water species have been widely found in the northern part of the Yellow Sea. Thaliaceans are found in the largest number and have the widest distribution, and have ranged as far north as the Yalu River for the past 30 years. Zooplankton populations in the warm water are moving from the low-latitude region towards the high-latitude region in response to climate warming. Cell numbers of the dominant species in the phytoplankton community in the Bohai Sea have decreased in the past 70 years and the original dominant species are losing their dominance due to the change in community composition. *Ceratium* sp. (Pyrrophyta) have become the mainly dominant species by succession, gradually replacing the dominant position of diatoms. The long-term changes in density and community structure of phytoplankton in the Bohai and the northern region of the Yellow Sea are the results of global climate change to some extent.

# W1 Posters

### W1-6368 (*Cancelled*)

## Marine ecosystem reestablishment − Seawater electrolyse with carbon capture

Jose M.P. **Silva**, Miguel J.A. Lopes and Ana R.P. Quintas

Curso de Química, Ambiente e Qualidade, Colégio Internato dos Carvalhos, Rua do Padrão, 83, Pedroso, 4415-284, Portugal
E-mail: zemanel@cic.pt

How is it possible to recover ecosystems by using both renewable energies and scrap iron?

The ocean acidification limits and/or conditions the atmospheric carbon dioxide fixation ($CO_2$) due to the instability of the hydrogencarbonate ion ($HCO_3^-$) in water. This way the formation of the phytoplankton and, directly, the whole food chain are compromised because carbohydrates are insufficient. Iron II ($Fe^{2+}$), which is important for the catalytic synthesis of chlorophyll, shows up in low concentrations as a result of mechanisms of reduction made more and more difficult by the low iron III ($Fe^{3+}$) concentration caused by, for example, overfishing and retention of river residues in dams.

Will it be possible to fight all the ominous causes at the same time? Of course it will! In this project, developed in a laboratory, the seawater electrolysis is done by using renewable energies. An inactive graphite cathode is used, where the reduction of the water molecule will happen and also a reactive iron anode, where oxidation will occur with transference of iron II into water. In the cathode, two things are released: hydrogen which is an important energetic vector to be used in fuel cells, and hydroxide ions ($HO^-$) that allow the reestablishment of pH by the balance of the hydrogencarbonate ion. In the anode, $Fe^{2+}$ ions are transferred into water. These act as catalyzer in the molecule synthesis of chlorophyll, which allow the beginning of the production process of carbohydrates through phytoplankton by capturing the atmospheric carbon dioxide and the release of oxygen.

### W1-6403

## Monitoring the impact of climate change on inland water bodies and fisheries by remote sensing and GIS technique a case study of Chalan beel (Bangladesh)

Hasan M. **Abdullah** and Yoshio Awaya

River Basin Research Center, Gifu University, 1-1 Yanagido, Gifu, 501-1193, Japan. E-mail: hasan@green.gifu-u.ac.jp

Like many other countries global warming has affected our weather patterns and disrupted our variability and trends in climate. Now Bangladesh is recognized worldwide as one of the countries most vulnerable to the impacts of global warming and climate change. Over the last ten years, Bangladesh has been ravaged by climatic extremes like floods, heavy downpour over short spell, cyclones, tornados, and droughts. This is due to its unique geographic location, dominance of floodplains, and low elevation from the sea. Though the adverse impacts are projected low lying coastline but floodplain ecosystems other than coastline which characterize Bangladesh is also equally vulnerable.

Bangladesh has vast resources that support fish production. Approximately 40,000 km² of permanent and seasonal water bodies provide complex habitat for around 260 species of fish. These include seasonally inundated floodplains and rivers, small and large seasonal and permanently flooded depressions called beels and haors respectively, and oxbow lakes known as baors. The legendary Chalan beel is the largest beel (wetland) situated in the north western region of Bangladesh, with an area of more than 350 km² during the rainy season and about 90 km² during the dry season.

Digitized temporal landsite (MSS, TM and ETM) image shows the variability of inundated area of Chalan beel due to drought caused by irregular rainfall and flooding caused by short spell heavy rainfall. Both the events are harmful for fish production as drought damage the fish habitat by drying the wet land and flood washout the fish from the water body and loss caused to fisherman. Present study would give a climate change impact scenario of Chalan beel.

# W2 Oral Presentations

**25 April, 9:05 (W2-6370)**

## Acidification of the global ocean: Observational evidence and projections to 2100 with the Canadian Earth System Model (CanESM)

Kenneth L. **Denman**[1,2], James Christian[1,2], Nadja Steiner[1,2] and Warren Lee[2]

[1] Fisheries and Oceans Canada, Institute of Ocean Sciences, P.O. Box 6000, Sidney, BC, V8L 4B2, Canada. E-mail: ken.denman@ec.gc.ca
[2] Environment Canada, Canadian Centre for Climate Modelling and Analysis, c/o University of Victoria, P.O. Box 3065, STN CSC, Victoria, BC, V8W 3V6, Canada

The 2007 Fourth Assessment Report (AR4) of Working Group I of the Intergovernmental Panel on Climate Change presented observational evidence of decreasing pH and calcium carbonate saturation state in the upper ocean. They estimate that global surface pH had decreased 0.1 since preindustrial times and project an additional decrease by 2100 of between 0.14 and 0.35, depending on which emission scenario is used. Since AR4 more observational evidence has accumulated, including 'corrosive' (pH <7.5 roughly where aragonite, the mineral form of calcium carbonate found in corals, becomes 'undersaturated') waters reaching depths as shallow as 20 m near the coast in wind-driven upwelling regions, and in the Canada Basin of the Arctic Ocean. Our earth system model CanESM, with dynamic carbon cycles on land and in the ocean including an embedded planktonic ecosystem model, was run with historical $CO_2$ emissions and the IPCC SRES 'A2' scenario for future emissions. We present global spatial distributions of surface pH and saturation state from our model up to 2100, and depth distributions along a North-South transect in the North Pacific Ocean, showing the shoaling of the aragonite saturation horizon (lysocline) since preindustrial times due to carbon dioxide from human activities reaching the ocean interior. An alternate scenario where emissions are rapidly reduced after 2050 partially mitigates the most severe impacts, but still results in a large expansion of undersaturated waters and a substantially reduced saturation state even in low latitude surface waters.

**25 April, 9:20 (W2-6149)**

## Metabolism and metamorphosis of coral larvae in acidified seawater

Masako **Nakamura**[1], Shun Ohki[1], Atsushi Suzuki[2] and Kazuhiko Sakai[1]

[1] Sesoko Station, Tropical Biosphere Research Center, University of the Ryukyus, Okinawa, 905-0227, Japan
E-mail: m_coral29@yahoo.co.jp
[2] Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, 305-8567, Japan

Scleractinian corals are the key organisms in coral reef ecosystems as reef builder, primary producer, and habitat provider. Maintenance of their populations is sustained by recruitment of planktonic larvae. Successful recruitment is directly affected by metamorphosis processes from the intermediate planktonic larval stage to the benthic juvenile stage. Nowadays, coral populations face to threats caused by the increase in the concentrations of atmospheric carbon dioxide ($CO_2$) emitted by anthropogenic activities and the subsequent increase in the amount of $CO_2$ dissolved in the oceans. Ocean acidification, induced by increased atmospheric $CO_2$, has been reported to impact on calcification of adult and juvenile corals and fertilization through the reduction in the number of motile sperm. However, our experiments suggested that the effect of acidified seawater on coral larvae were less significant than on those stages. In the present study, we first assessed metabolism ($O_2$ consumption) of coral larvae under different pH conditions to understand the mechanisms underlying the stress response of the larvae to acidified seawater. Second, we examined whether coral larvae are able to maintain metamorphosis capability under acidified conditions. As a result, metabolism of coral larvae tended to decrease with pH decrease. Moreover, metamorphosis was significantly diminished in reduced pH conditions. This implies that ocean acidification may negatively impact the metamorphosis process of coral larvae, resulting in recruitment failure. The present study would contribute to deepen the knowledge on coral population maintenance in a high $CO_2$ world.

**25 April, 9:35 (W2-6259)**

## Effects of ocean acidification on the growth of the flat-tree oyster, *Isognomon alatus* (Gmelin, 1791)

Lailah G. **Lartey-Antwi**[1] and Andreas J. Andersson[2]

[1] Department of Oceanography and Fisheries, University of Ghana, P.O. Box LG 99, Legon-Accra, Ghana
E-mail: lailah.lailah@gmail.com
[2] Bermuda Institute of Ocean Sciences, 17 Biological Station, St. George's, GE01, Bermuda

Anthropogenic emissions of carbon dioxide ($CO_2$) are rapidly increasing the atmospheric concentration of $CO_2$ and reducing the pH of the surface ocean, a phenomenon referred to as ocean acidification. Ocean acidification could have negative effects on marine organisms. As a result of increasing seawater $CO_2$ and decreasing pH, the availability of carbonate ions and the saturation state with respect to calcium carbonate minerals will decrease. As a consequence, the formation of calcareous hard-parts will become increasingly challenging for marine calcifying organisms such as corals, coralline algae, crustaceans, mussels, oysters and clams. This study provides information on the effects of increasing $CO_2$ and decreasing pH on the growth rate of *Isognomon alatus* (flat-tree oyster) under controlled laboratory conditions as well as in a natural environment. In controlled laboratory experiments, *I. alatus* lost weight and experienced negative growth rates of $-0.56 \pm 0.36$ mg $g^{-1}day^{-1}$ under average $pH_{total}$ values of 7.8 compared to a loss of $-0.26 \pm 0.23$ mg $g^{-1}day^{-1}$ under average ambient $pH_{total}$ conditions of 8.1. In contrast, *I. alatus* incubated in a natural environment showed gain in weight and positive growth despite exposure to pH levels (~7.4) during low tide significantly lower than those experienced in the laboratory. These results suggest that rising $CO_2$ and ocean acidification could have drastic negative consequences on *I. alatus*, but that additional factors (*e.g.*, food availability) need to be considered in evaluating the response of this marine calcifier to these ongoing perturbations.

**25 April, 9:50 (W2-6361)**

## Effects of diurnal $pCO_2$ fluctuation on sea urchin larvae: A preliminary report

Ryota **Suwa** and Yoshihisa Shirayama

Seto Marine Biological Laboratory, Field Science Education and Research Center, Kyoto University, 459 Shirahama, Wakayama, 649-2211, Japan. E-mail: ryota@zenno.jp

Ocean acidification, caused by increased atmospheric carbon dioxide ($CO_2$) concentrations, is predicted to occur in the future. Many studies have examined the impacts of increased $CO_2$ or lowered pH on marine organisms. However, previous studies have applied fixed $pCO_2$ or pH values for assessments, although there is diurnal fluctuation of $pCO_2$ in the sea where $pCO_2$ is low in daytime and high at night because of photosynthesis and respiration. The $pCO_2$ of the shallow waters around Shirahama, Wakayama, Japan where samples were collected for this study fluctuates ±200 ppm diurnally. This fluctuation has the possibility to cause damage or recovery of marine organisms. A high-accuracy $pCO_2$ system which enables simulation of the diurnal $pCO_2$ fluctuation with running seawater was evaluated and used to assess the impact of diel $pCO_2$ fluctuation on sea urchin larvae. Sea urchins are an important fishery resource in Japan and their larval stage is known to be vulnerable to acidified seawater. Two $pCO_2$ conditions of 400 and 800 ppm with computer-programmed gradual $pCO_2$ fluctuation and three fixed conditions of 230, 400 and 800 ppm were prepared using this system and the effects of these conditions on the larval morphology of the sea urchins *Tripneustes gratilla* and *Hemicentrotus pulcherrimus* were examined. Preliminary results of these experiments will be included in this presentation.

**25 April, 10:05 (W2-6303)**

## Overview of the impacts of ocean acidification on the early development of fishes and shellfishes

Haruko **Kurihara**

Transdisciplinary Research Organization for Subtropical Island Studies, University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa, 903-0213, Japan. E-mail: harukoku@e-mail.jp

Ocean acidification is now likely to affect a wide range of marine organisms. This presentation will review available studies evaluating the effects of ocean acidification on the early developmental stages of different marine organisms including commercially important species (sea urchins, bivalves, crustaceans and fishes). The studies generally demonstrated evidence that 1. Ocean acidification impacts the early developmental stages of several fishes and shellfishes 2. The early developmental stages are principally vulnerable to ocean acidification; 2. Different developmental stages (*e.g.* fertilization, larva, settlement stages) are affected in different ways, and generally, the stage in which precipitation of calcium carbonate starts is most sensitive to the ocean acidification; 3. The capacity for tolerance differs between species; and 4. The early developmental stages are synergistically affected by ocean acidification and global warming. Considering that the viability of early developmental stages directly affects the population size of marine organisms, the projected oceanic environmental change due to the increase of atmospheric $CO_2$ will potentially affect fish and shellfish populations, which may in turn impact the sustainability of our future marine food sources.

**25 April, 10:40 (W2-6311), page 213**

**25 April, 10:55 (W2-6243)**

## Mathematical approach to modeling the effects of ocean acidification on the pteropod and pink salmon population

Kehinde **Salau**

Mathematical, Computational and Modeling Sciences Center, Arizona State University, Physical Sciences A-Wing, P.O. Box 871904, Tempe, AZ, 85287-1904, USA. E-mail: kehinde.salau@gmail.com

Ocean acidification serves to be a problematic extension of increased atmospheric $CO_2$ content, especially when the future of marine ecosystems and organisms is concerned. An increase in aquatic $CO_2$ content decreases oceanic pH and intensifies shoaling saturation depths of the $CaCO_3$ minerals, calcite and aragonite. One species that serves to be greatly affected by ocean acidification is the euthecosomatous pteropod, which may suffer shell and skeleton deterioration and/or growth delay. There are also bottom-up consequences: the abundant pink salmon in the North Pacific is an important harvested population. Juvenile pink salmon have been known to prey heavily on pteropods, creating a three-tier interaction between plankton, fish and humans. A discrete stage-structured model is developed to investigate the dynamics of this three-tier interaction and to generate questions and ideas about what happens to such interactions in the wake of ocean acidification.



**25 April, 11:10 (W2-6291)**

## Effects of $CO_2$-driven ocean acidification and warming on early development of fish

Atsushi **Ishimatsu**[1], Atsuko Fukuda[1] and Haruko Kurihara[2]

[1] Institute for East China Sea Research, Nagasaki University, Tairamachi 1551-8, Nagasaki 851-2213, Japan
E-mail: a-ishima@nagasaki-u.ac.jp

[2] Transdisciplinary Research Organization for Subtropical and Island Studies, The University of Ryukyus, Nishihara, Okinawa, 903-0213, Japan

Most efforts in ocean acidification research have been directed towards understanding how biocalcification is affected by high $CO_2$/low pH seawater. In contrast, little attention has been paid to effects on fish despite their paramount importance in marine ecosystems as predators and food resources for humans. Moreover, there are limited data on the combined impacts of ocean acidification and warming. Our recent results have demonstrated

the deleterious impacts of elevated temperature and $CO_2$ on early development of the tropical clownfish (*Amphiprion clarkii* and *A. ocellaris*), although $CO_2$ sensitivity differed between the two species. Embryonic survival of *A. clarkii* was 80-100% at 29°C but 0% at 31°C in both control and high $CO_2$ groups (1000 matm). Similarly, embryonic survival of *A. ocellaris* was comparable between the two groups at 29°C (80-100%), but at 32°C survival remained high in the control but was only 0-30% in the high $CO_2$ group. There was no significant difference in external morphology, yolk absorption or cardiac activities for surviving individuals. No clear difference was detected in larval survival, body length or body weight between control and high $CO_2$ groups of *A. clarkii* at 29°C. These results suggest that some fish could become extinct in future oceans if they cannot acclimate to the rapid rise of $CO_2$ and temperature. The results of an ongoing study on $CO_2$ effects through several generations of the seawater medaka (*Oryzias javanicus*) will also be discussed.

**25 April, 11:25 (W2-6128)**

## Ocean acidification does not affect the early life history development of a tropical marine fish

Philip L. **Munday**[1], Monica Gagliano[2], Simon Thorrold[3], Jennifer M. Donelson[1] and Danielle L. Dixson[1]

1 ARC Centre of Excellence for Coral Reef Studies, and School of Marine and Tropical Biology, James Cook University, Townsville, QLD, 4811, Australia. E-mail: Philip.Munday@jcu.edu.au
2 Centre for Evolutionary Biology, School of Animal Biology, University of Western Australia, Crawley, WA, 6009, Australia
3 Woods Hole Oceanographic Institution, Woods Hole, USA

Little is known about how fishes and other non-calcifying marine organisms will respond to the increased levels of dissolved $CO_2$ and reduced seawater pH that are predicted to occur over the coming century. We reared juveniles of the spiny damselfish, *Acanthochromis polyacanthus* in seawater simulating a range of ocean acidification scenarios for the next 50-100 years (current-day, 550ppm, 750ppm, 1030 ppm atmospheric $CO_2$) to test how early life history and developmental traits might be affected. Newly-hatched clutches were divided into the different treatments and reared for three weeks. There was no effect of elevated $CO_2$ on the mortality or growth rates of juveniles. There were also no consistent differences in the development of major skeletal elements between control and treatment fish. Finally, otoliths (composed of aragonite) did not differ in size, shape, asymmetry (between left and right) or chemical composition between controls and treatments. These results, in combination with results from experiments using the orange clownfish, *Amphiprion percula*, suggest that ocean acidification, in isolation, will not have a significant effect of the early life history development of reef fishes.

**25 April, 11:40 (W2-6390)**

## Effects of elevated $pCO_2$ on fish otoliths – Results, inference, and experimental design

David M. **Checkley**, Jr.

Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA, 93093-0218, USA. E-mail: dcheckley@ucsd.edu

The growth of otoliths in fish and statoliths in invertebrates may vary with elevated $pCO_2$. I present our recent findings of accelerated otolith growth of young white seabass (*Atractoscion nobilis*) under elevated $pCO_2$ (Checkley, Dickson *et al*. 2009 Science 324:1683) in the context of past, slow and future, rapid environmental change, and of evolution, adaptation, and ontogeny. Past and future $pCO_2$ experienced by teleost fish may vary over similar ranges but on vastly different time scales, with implications for adaptation. I also discuss the design of short-term experiments intended to allow inference about the effects of long-term, gradual change in $pCO_2$ on the growth of otoliths and statoliths.

# W2 Posters

### W2-6065

## Variability in pH values and the potential influence of ocean acidification on oysters and other shellfish in Pacific Northwest estuaries

Steven S. **Rumrill**[1,2], Alicia R. Helms[2] and Adam S. De Marzo[2]

[1] University of Oregon, Oregon Institute of Marine Biology, 63466 Boat Basin Dr., Charleston, OR, 97420, USA
E-mail: Steve.Rumrill@state.or.us
[2] South Slough National Estuarine Research Reserve, Estuarine and Coastal Science Laboratory, P.O. Box 5417, Charleston, OR, 97420, USA

Increased $pCO_2$ values along the continental shelf of the North Pacific have the potential to alter the carbonate chemistry of surface waters and disrupt calcification for several species of commercially and recreationally important shellfish. Acidification of nearshore ocean waters is a serious concern along the shoreline and estuaries in Washington, Oregon, and northern California where the California Current system is characterized by intense seasonal upwelling, elevated $pCO_2$ values, and periodic hypoxia. Commercial mariculture of Pacific oysters (*Crassostrea gigas*) and other shellfish contributes $110 million annually to the regional economy, and the estuaries provide habitat for recovering populations of Olympia oysters (*Ostrea lurida*) and recreational harvests of several species of clams, crabs, and burrowing shrimp. Time-series measurements of dissolved oxygen and pH values were recorded over 2002-09 with a YSI-6600 EDS multi-parameter datalogger deployed in the tidal channel of the South Slough estuary (Coos Bay, OR). Estuary pH values typically ranged between 7.7 and 8.3 each day with lowest values in mid-morning and highest values in mid-afternoon. The daily pH cycle appears to be driven by net photosynthesis and respiration within the estuary. We also observed a long-term shift in estuary pH values from a low mean value of 7.9 in 2002 to a higher mean value of 8.1 in 2009. It is likely that pH variability in the estuaries differs substantially from the ocean, and carbonate saturation conditions for the early life-history stages of oysters and other shellfish may be only indirectly coupled to acidified waters further offshore.

### W2-6237

## Increase in the Si:N drawdown ratio of the Bering Sea phytoplankton community under high $CO_2$ and iron-limited conditions

Koji **Sugie**[1], Hisashi Endo[2], Koji Suzuki[2,3] and Takeshi Yoshimura[1]

[1] Environmental Science Research Laboratory, Central Research Institute of Electric Power Industry, 1646 Abiko, Abiko, Chiba, 270-1194, Japan. E-mail: sugie@criepi.denken.or.jp
[2] Graduate School of Environmental Science, Hokkaido University, Kita 10 Nishi 5, Kita-ku, Sapporo, Hokkaido, 060-0810, Japan
[3] Faculty of Environmental Earth Science, Hokkaido University, Kita 10 Nishi 5, Kita-ku, Sapporo, Hokkaido, 060-0810, Japan

We report the results of an on-deck $CO_2$ and iron perturbation experiment examining nutrient drawdown ratio by the natural oceanic Bering Sea phytoplankton community during late summer 2009. Partial pressure of $CO_2$ in the air injected into the incubation bottles was set at 180, 380, 600 and 1000 ppm for iron-added (5 nmol $L^{-1}$) treatments and at 380 and 600 ppm for unamended controls. During the 1 week batch incubation, $CO_2$-adjusted air was bubbled directly into the incubation bottles. The growth rates were higher in iron-added treatments compared to the controls, suggesting phytoplankton in the controls were iron-limited. The maximum chlorophyll *a* concentrations were ~25 µg $L^{-1}$ in all iron-added bottles, and ~10 and ~6 µg $L^{-1}$ in the controls of 380 and 600 ppm, respectively. Nitrate, nitrite, phosphate and silicic acid were exhausted on days 4 or 5 in the iron-added bottles while only silicic acid was depleted on day 5.7 in the 380 ppm control. We found the Si:N drawdown ratio of the 600 ppm control (2.34 ± 0.05) was significantly higher than that in 380 ppm of 1.89 ± 0.02 ($p<0.01$, ANOVA). The high Si:N drawdown ratio in the 600 ppm was derived from the combination of higher Si:P and lower N:P drawdown ratios compared to the 380 ppm treatment. The Si:N drawdown ratio in the iron-added bottles did not change at 0.76 due to $pCO_2$ variation. Our results suggest that in iron-limited regions the future high-$CO_2$ world may lower the carrying capacity for silicifiers such as diatoms.

**W2-6249**

## Effects of ocean acidification on the early developmental stages of Ezo abalone *Haliotis discus hannai*

Hideki **Takami**[1], Ryo Kimura[2], Tsuneo Ono[3], Toshihiro Onitsuka[2] and Yukihiro Nojiri[4]

[1] Tohoku National Fisheries Research Institute, Fisheries Research Agency, 3-27-5 Shinhama, Shiogama, Miyagi, 985-0001, Japan
E-mail: htakami@affrc.go.jp
[2] National Research Institute of Fisheries Science (Yokosuka Station), Fisheries Research Agency, 6-31-1, Nagai, Yokosuka, Kanagawa, 238-0316, Japan
[3] Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116, Katsurakoi, Kushiro, Hokkaido, 085-0802, Japan
[4] Center for Global Environment Research, National Institute for Environmental Study, 16-2, Onogawa, Tsukuba, Ibaraki, 305-8506, Japan

At the PICES 2009 Annual Meeting, we reported that elevated $pCO_2$ above 1500 ppm had considerably harmful effects on fertilization and larval development of Ezo abalone *Haliotis discus hannai*, an economically valuable gastropod. In this study, we focused on the response of post-larval Ezo abalone to increased $pCO_2$, especially metamorphosis and post-larval growth rates using a highly accurate $CO_2$ manipulation system. Larval abalone, which had been reared at $pCO_2$ concentrations from 400 to 2000 ppm, were induced to metamorphose by addition of 1.5 μM of g-aminobutyric acid and 300 μg/ml of Streptomycin sulfate BP. Metamorphosed post-larvae were also reared at $pCO_2$ concentrations of 400-2000 ppm to monitor growth rate. The elevated $pCO_2$ did not affect the percentage of larvae metamorphosing into post-larvae. Shell growth rates of post-larvae at >1500 ppm were significantly reduced compared with those at <1000 ppm. Scanning electron microscope images of post-larval shells from >1000 ppm showed abnormal development suggesting problems with shell deposition and/or increased shell dissolution. These results and those from the previous study indicate that $pCO_2$ >1000 ppm reduced developmental performance of Ezo abalone in early life stages. If the oceans continue to acidify as expected, the population of Ezo abalone may be endangered due to recruitment failure of larvae and post-larvae by the year 2100.

**W2-6287**

## Impact of a high-$CO_2$ environment on Japanese Ivory-shell, *Babylonia japonica*

Jun **Kita**

Demonstration Laboratory, Marine Ecology Research Institute, 4-7-17 Arahama, Kashiwazaki, Niigata, 945-0017, Japan
E-mail: kita@kaiseiken.or.jp

The Japanese Ivory-shell, *Babylonia japonica*, (Neogastropoda: Buccinidae) inhabits sandy bottoms in temperate shallow waters of Japan. They are scavengers in the inshore ecosystem and important fisheries species. I investigated the effects of a high-$CO_2$ environment on reproductive properties such as egg production and embryonic development, together with acute mortality. To test reproductive properties, adult Ivory-shells were maintained in seawater at normal conditions ($pCO_2$=560 ppm) and at three high-$CO_2$ conditions: $pCO_2$=1,600ppm, $pCO_2$=5,700 ppm and $pCO_2$=16,000 ppm for 80 days. To test acute mortality, adult Ivory-shells were kept in seawater at normal condition ($pCO_2$=570 ppm) and at three high-$CO_2$ conditions: $pCO_2$=68,000 ppm, $pCO_2$=97,000 ppm and $pCO_2$=150,000 ppm for 96 hours. The total number of spawned egg capsules and the mean egg number per capsule showed no significant difference between normal and high-$CO_2$ conditions. The mean number of unsuccessful embryonic developments per capsule showed a significant difference at 5700 ppm, and all eggs at 16000 ppm showed no successful embryonic development. However, when the capsules were transferred to normal seawater conditions immediately after the spawning, all eggs in high-$CO_2$ conditions showed normal embryonic development. The acute mortality test indicated that adult Ivory-shells were highly tolerant to high-$CO_2$; they survived even at 97,000 ppm but died at 150,000 ppm. These results suggested that early life stages of Ivory-shell are sensitive to high-$CO_2$ environments.

**W2-6288**

## Effects of $CO_2$ induction on development of Brine Shrimp (*Artemia franciscana*)

Umme **Salma** and Hyun Woo Kim

Department of Marine Biology, Pukyong National University, 599-1 Daeyeon 3-dong, Nam-gu, Busan, 608-737, R Korea
E-mail: ummesalma.bau@gmail.com

Continuous absorption of anthropogenic $CO_2$ by the ocean is one of the major causes of ocean acidification. Surface ocean pH has reached 8.1 which is approximately 0.1 units less than the estimated pre-industrial value 200 years ago. Researchers predict that if $CO_2$ emissions continue to rise on current rate, ocean average pH will reach 7.8 by the end of this century. Effects of ocean acidification are not only disruption of calcification of marine calcifying organisms but also interfere reproductive or physiological processes in other marine species. Susceptibility of numerous marine organisms such as corals, mollusks, crustaceans and sea urchins have been reported, but in our experiment Brine Shrimp (*Artemia franciscana*) is taken as a model due to its ease of culture, growing and maintenance facilities. Consequently, we investigated the effects of culture in $CO_2$-enriched seawater on the life history stages of Brine Shrimp. We designed continuous $CO_2$ supplied water tanks and divided the experimental groups into three differents pH 7.00, 7.30 and 7.60 and then hatching success, survival and growth rate were measured through the developmental period. Native seawater was used as control. These results suggest that raising $CO_2$ will affect hatching, survival and growth of marine organisms ultimately affect marine larval production. Further aims of our study are to isolate and characterize the genes affected by higher $CO_2$, as gene expression is influenced by variations of environmental conditions such as different pH, salinity or temperature, to obtain a better idea about the physiological change of marine animals which follows ecological change.

**W2-6311 (*moved to Oral Section, 10:40 am, page 209*)**

## Climate change impacts (ocean acidification and temperature) on the metabolic scope and activity of nektonic organisms: A crustacean example

Awantha **Dissanayake**[1], Atsushi Ishimatsu[1], Haruko Kurihara[2] and So Kawaguchi[3]

[1] Institute for East China Sea, Nagasaki University, Tairamachi 1551-7, Nagasaki, 851-2213, Japan. E-mail: awantha@nagasaki-u.ac.jp
[2] Transdisciplinary Research Organization for Subtropical and Island Studies, The University of Ryukyus, Nishihara, Okinawa, 903-0213, Japan
[3] Australian Antarctic Division, Channel Highway, Kingston, Tasmania, 7050, Australia

Continuous increasing carbon dioxide ($CO_2$) emissions are elevating atmospheric concentrations of $CO_2$, which in turn are increasing simultaneously the $CO_2$ concentrations (*i.e.* hypercapnia) and acidity of the world's oceans (ocean acidification; OA). Elucidating the impacts of OA associated climate change (OA-CC) upon the biota is of paramount importance as the human population increases, and thus the dependency upon global fisheries as a source of nutrition. Predicting OA-CC impacts on marine ecosystems and fisheries is difficult due to the current lack of knowledge of the ability of individual species and key functional groups to adapt to climatic change. In general, however, invertebrates, in particular, crustaceans are more sensitive to OA-CC effects than fish. This study addresses physiological impacts of OA-CC in a model crustacean group (Decapoda: Penaeidae) indicative of the swimming capability of other natantia occupying various ecosystems (shallow-water coastal and open ocean). Penaeid individuals (*Metapenaeus joyneri*) exposed to both hypercapnia (1% $CO_2$) and temperature (15 and 20°C) demonstrated a new regulatory set-point in osmotic capability with a concomitant shift in haemolymph pH, compared with control individuals (ambient/present day $CO_2$ levels). OA-CC exposure resulted in a significant 30% reduction of the critical swimming ability of Penaeids (defined as swimming endurance). The observed reduced swimming ability may be due to reduced metabolic scope [*i.e.* difference between active and basal metabolic rate (assessed as oxygen consumption rates)] as observed by a significant 30% reduction of active metabolic rates but no difference in alteration of basal metabolic rates. OA-CC impacts may therefore cause organisms to shift energy utilisation towards maintenance (*i.e.* osmoregulatory ability) thereby, resulting in a decrease in both aerobic metabolic scope and energy-demanding activities *e.g.* swimming. In conclusion, in order to improve our predictive abilities of OA-CC effects, laboratory-derived empirical evidence elucidating the physiological mechanisms of OA-CC impacts in key model groups, must be elucidated in order to predict the status of global fisheries.

**W2-6344**

## Molecular technique analysis of effect of ocean acidfication on brine shrimp

Bo Kwang **Kim** and Hyun Woo Kim[2]

Department of Marine Biology, Pukyong National University, Yonghoro 51, Nam-gu, Busan, 608-737, R Korea
E-mail: coke0727@naver.com

A major concern of anthropogenic effects on marine ecosystems is ocean acidification. As $CO_2$ increases as a result of human activities, average pH has been decreasing since the mid 19th century. Changes in pH in ocean ecosystems cause harmful effects on marine animal mating, hatching, survival and feeding. Among them, harmful effects on the animals with exoskeletons may be more serious than other species. In the present study, we designed a seawater tank to evaluate the effects of different carbon dioxide levels. Using brine shrimp (*Artemia franciscana*) as a model system, animals were kept for two weeks in two different pH conditions (pH 7.00 and pH 7.8), which were adjusted by continuous flow of gaseous $CO_2$. To isolate genes which were influenced by pH, we carried out deferential display RT-PCR using annealing control primers. A total of 120 different primer sets were used for this experiment and isolated genes were characterized. Quantitative PCRs were also performed to measure the change of each transcript by different pH. This study would help us to understand cellular mechanisms in the changing marine environment and to estimate future results from ocean acidification.

**W2-6422**

## Physiology to Fisheries: starting steps and future approaches

Will Le Quesne and John K. **Pinnegar**

Centre for Environment, Fisheries and Aquaculture Sciences, Lowestoft Laboratory, Pakefield Rd., Lowestoft, Suffolk, NR33 0HT, UK
E-mail: will.lequesne@cefas.co.uk

Whilst ocean acidification (OA) operates at the cellular level it is the population and ecosystem level responses that are of societal concern. Given predictions about potential physiological impacts on commercial species and other ecosystem components there is a strong desire to assess potential OA impacts on fisheries. Assessing potential OA impacts on fisheries requires scaling up from physiological processes to ecological processes and examination of the interaction between physiology and ecology. Given the difficulty of large-scale long-term manipulative studies, predictive ecological modelling will form a significant strand in assessment of OA impacts. To conduct this in a timely manner, where possible it is desirable to emulate the impacts of OA through parameter modification in existing ecological and fisheries model structures. In some instances parameters within model could be directly modified on the basis of physiological studies, however in other instances experimental results will have to be objectively or subjectively interpreted to inform reparameterization. A variety of modelling formats exist that aim to emulate population and/or ecosystem processes with fundamentally different model structures. This allows different physiological effects to be emulated across a variety of models. To incorporate ecology into OA studies it is necessary to develop a dialogue between physiologist and ecologists to assess how OA effects can be emulated within existing predictive model structures, and whether all relevant effects of OA can currently be captured. This poster aims to facilitate this dialogue by posing some questions and by providing an example of a starting step down this road.

# W3 Oral Presentations

**25 April, 9:30 (W3-6365)**

## Changes in mesozooplankton size structure along a trophic gradient and implications for the growth of small pelagic fish

Ryan R. **Rykaczewski**

University Corporation for Atmospheric Research, Geophysical Fluid Dynamics Laboratory, 201 Forrestal Rd., Princeton, NJ, 08540-6649, USA
E-mail: ryan.rykaczewski@noaa.gov

Previous laboratory observations indicate that zooplankter sizes and concentrations influence the growth and behavior of individual sardine and anchovy. I build upon these relationships by considering how growth rates and behavior may be influenced by observed changes in plankton size structure along a trophic gradient. Mesozooplankter sizes and concentrations were measured for samples collected across a trophic gradient in the California Current Ecosystem, with coincident measures of phytoplankton size structures and ecosystem conditions. I found a clear distinction between mesozooplankter sizes in samples collected from oligotrophic and eutrophic communities, with the relative abundance of large individuals being greater in areas where upwelling conditions enhanced nutrient availability and increased abundance of larger phytoplankters. The relative contributions of smaller zooplankters were greater in oligotrophic waters. In light of the observed variability in the biomasses and size structures of phytoplankton and zooplankton communities, I estimated the potential growth rates of sardine and anchovy using previously established models of ingestion, absorption, excretion, and respiration. These bioenergetic models suggest that the potential for growth of anchovy is dependent on the community structure of nearshore, eutrophic waters where large zooplankters are abundant. Growth of anchovy is unlikely in offshore, oligotrophic waters. In contrast, growth of sardine is possible under more oligotrophic conditions and influenced by oceanographic conditions in the offshore region of the ecosystem. These results suggest that accurate representation of plankton size structure may be an important component in mechanistic models of sardine and anchovy populations.

**25 April, 9:55 (W3-6027)**

## A consistent nutrient to fish model for the Baltic Sea

Wolfgang **Fennel**

IOW, Seestr. 15, Rostock, 18119, Germany. E-mail: wolfgang.fennel@io-warnemuende.de

This talk presents a consistent theoretical approach to bridge the gap between biogeochemical models and fish-production models. The linkage of the different models requires coupling of a NPZD-model and fish production model to generate a NPZDF-model, (or WFM -Warnemuende Food web Model). As example system the Baltic Sea is chosen, where the fish dynamics is dominated by two prey species (sprat and herring) and one predator (cod). However, the approach can also be applied to other systems.

The dynamics of the fish model is driven by size-dependent predator-prey interactions while the interaction between the model components is established through the feeding of prey fish on zooplankton and recycling of fish biomass to nutrients and detritus. The model conserves strictly mass. In order to demonstrate the model performance, several loading and fishing scenarios are discussed. In particular, the effects of eutrophication and fishery scenarios are addressed. The comprehensive NPZDF-model also opens the possibility to analyse the effects of choices for parameterizations of unresolved processes in truncated NPZD models. Simulations of scenarios show that the observed order of magnitude and the structure of the species of catches can be reproduced, but the description of the phases needs further consideration. The model enables building the fish model into a three-dimensional ecosystem model of the Baltic Sea or other systems.

**25 April, 10:40 (W3-6297)**

## Development and implementation of a 3D-IBM in the north Aegean Sea (eastern Mediterranean) that describes the full life cycle of anchovy

George **Triantafyllou**[1], Kostas Tsiaras[1], Stylianos Somarakis[1], Dimitris Politikos[1,2] George Petihakis[1], Annika Pollani[1], Shin-ichi Ito[3] and Bernard A. Megrey[4]

1 Hellenic Centre for Marine Research, Anavissos, 19013, Greece. E-mail: gt@ath.hcmr.gr
2 Department of Mathematics, School of Applied Mathematical and Physical Sciences, National Technical University of Athens, Zografou Campus, Athens, 157 80, Greece
3 Tohoku National Fisheries Research Institute, Fisheries Research Agency, 3-27-5 Shinhama-cho, Shiogama, Miyagi, 985-0001, Japan
4 National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA, 98115, USA

An Individual Based Model (IBM) that describes the full life of the cycle of the European anchovy (*Engraulis encrasicolus*) is developed and implemented in the north Aegean Sea (eastern Mediterranean Sea) in the framework of SESAME-REPRODUCE-MEECE EU projects. For modeling purposes, the north Aegean population of anchovy is represented by a number of "Super Individuals" (SI) with attributes (x, y, z coordinates, population, age, length, weight of the fish). This Lagrangian model is online two-way coupled with a biophysical model based on Princeton Ocean Model (POM) and European Regional Seas Model (ERSEM). Processes at the level of organism are described by a bioenergetics model following the basic structure of the NEMURO.FISH model, while a population dynamics model describes the evolution of the number of individuals in each age class, depending on fishing and natural mortality. The SIs are transported as passive tracers while in the stage of eggs and early larvae. For the next stages, migration dynamic programming methods are introduced that allow anchovy to "move" in optimal areas by balancing food resources and processes due to memory and learning. The vertical SI distribution is a function of food availability, optimal temperature and diurnal migration. Model results reasonably describe the distribution and biomass of anchovy compared to available data, establishing a significant mathematical tool for managing sustainable resources of anchovy. These quantitative approaches are useful for the investigation and prediction of the effect of climate changes on fish populations and the functioning of oceanic ecosystems. Model performance together with sensitivity analysis are presented and discussed.

**25 April, 11:05 (W3-6267)**

## Potential impact of climate change on Pacific saury

Shin-ichi **Ito**[1], Takeshi Okunishi[2], Michio J. Kishi[3,4] and Muyin Wang[5]

1 Tohoku National Fisheries Research Institute, FRA, 3-27-5 Shinhama-cho, Shiogama, Miyagi, 985-0001, Japan
E-mail: goito@affrc.go.jp
2 National Research Institute of Fisheries Science, FRA, Kanazawa-Ku, Yokohama, Kanagawa, 236-8648, Japan
3 Faculty of Fisheries Sciences, Hokkaido University, Sapporo, Hokkaido, 060-0813, Japan
4 Frontier Research Center for Global Change, JAMSEC, Yokohama, Kanazawa, 236-0001, Japan
5 Joint Institute for the Study of Atmosphere and Ocean, University of Washington, Seattle, WA, USA, 98115

An ecosystem-based bioenergetics model NEMURO.FISH (North Pacific Ecosystem Model for Understanding Regional Oceanography.For Including Saury and Herring) was developed and successfully reproduced realistic growth of Pacific saury with parameters determined mainly from field observations. The model is composed of three ocean domain boxes and saury is assumed to migrate between those boxes. The model is very simple but it also reasonably captures the growth difference between autumn, winter, and spring-spawned cohorts. This model was used to investigate responses of Pacific saury to global warming using the sea surface temperature (SST) of current climatology and a global warming condition generated by MIROC3.2 coupled atmospheric–ocean model output with A2 scenario. The saury showed a decrease in both wet weight and body length under global warming because of less prey plankton density. The migration pattern was modified by increasing SST and reducing the size of saury. Under global warming, higher SST in the mixed water region prevented the southern migration of saury in the first winter and delayed it in the second winter. As a result, egg production was enhanced by a higher availability of prey zooplankton in the mixed water region. Results may greatly depend on the magnitude of SST increase. We will compare the results using several climate model outputs at the presentation.

**25 April, 11:30 (W3-6211)**

## Development of a climate-to-fish-to-fishers model: Data structures and domain decomposition

Kate **Hedström**[1], Jerome Fiechter[2], Kenneth A. Rose[3], Enrique N. Curchitser[4], Miguel Bernal[4], Shin-ichi Ito[5] and Bernard A. Megrey[6]

1 Arctic Region Supercomputing Center, 909 Koyukuk Dr., Suite 105, Fairbanks, AK, 99775, USA. E-mail: kate@arsc.edu
2 Ocean Sciences Department, University of California, Santa Cruz, CA, 95064, USA
3 Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA, 70803, USA
4 Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd., New Brunswick, NJ, 08901, USA. Permanent address: Instituto Español de Oceanografía, Centro Oceanográfico de Cádiz, Puerto Pesquero, Muelle de Levante, s/n, Apdo. 2609, 11006, Cádiz, Spain. E-mail: miguel.bernal@cd.ieo.es
5 Tohoku National Fisheries Research Institute, Fisheries Research Agency, 3-27-5, Shinhama-cho, Shiogama-city Miyagi, 985-0001, Japan
6 Alaska Fisheries Science Center-NOAA, 7600 Sand Point Way NE, Seattle, WA, 98115, USA

In the accompanying Rose presentation, a coupled ecosystem model for physics to fish to fishing fleets will be introduced and preliminary results will be shown. The model has been configured for examining the long-term population cycles of anchovy and sardine in the California Current system. This presentation will focus on the numerical methods and computing considerations for dynamically coupling the physics, lower trophic level, and upper trophic level models. The physics is represented by the Regional Ocean Modeling System (ROMS), which has been designed to run on parallel architectures using the Message Passing Interface (MPI) that is common on the current generation of supercomputers. The lower trophic level model is a version of the NEMURO nitrogen-phytoplankton-zooplankton model. The fish community is represented using a full life cycle, individual-based approach. When combining the models, which are a mix of Eulerian and Lagrangian approaches, care must be taken to ensure that the modeling system continues to function on tens of processors with many thousands of individuals without running into resource limitations – or worse, results that depend on the number of processors. We will describe several of the numerical algorithms we are using in our coupled model, including those for spatially-locating eggs from spawning and scaling the predator-prey interactions among the fish species represented in the model and between the fishers and the fish.

**25 April, 11:55 (W3-6401)**

## Should climate-to-fish-to-fishers models be assembled from existing models?

Kenneth A. **Rose**

Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA, 70803, USA
E-mail: karose@lsu.edu

The development of climate-to-fish-to-fishers (end-to-end) models is a very active area of research. The concept is very appealing and attractive. If such models can be developed, they offer promise in addressing bottom-up and top-down effects of climate change and would allow for a major step towards ecosystem-based fisheries management. There are several major efforts underway to develop end-to-end models. These approaches differ in several ways: single-species versus multi-species versus community representations, direct linkage to 3-dimensional physics versus very simplified spatial domains, mass versus individual versus size-based currencies, new versus old approaches to predator-prey interactions, and how behavioral movement is represented. I use several of these ongoing model development efforts to illustrate these differences, including our group's effort in developing an end-to-end modeling framework within the widely-used ROMS (Regional Ocean Modeling System) circulation model. We have opted to piece together an end-to-end model for sardine and anchovies from existing submodels (ROMS, NEMURO, individual-based bioenergetics for fish) with the addition of a bioeconomics-based fishing fleet submodel. I will use this example, with others, to illustrate some the old issues that arise with developing complicated models in general, as well as new issues specific to the development of end-to-end models. These issues call into the question the seemingly straightforward approach of simply linking existing submodels, and these issues should be carefully considered when developing any end-to-end model.

# W4 Oral Presentations

**25 April, 9:10 (W4-6121)**

## Setting the stage for predicting climate change effects on Pacific salmon – How has salmon abundance varied during the last 85 years and why?

James R. **Irvine**[1] and Masa-aki Fukuwaka[2]

[1] Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
E-mail: james.irvine@dfo-mpo.gc.ca
[2] Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsurakoi, Kushiro, Hokkaido, 085-0802, Japan

Understanding reasons for previous changes in salmon abundance can help anticipate climate related changes in the future. We review regional differences in abundance trends, present time series of hatchery releases and salmon survivals, and relate changing patterns in salmon abundance and survival to major climate indices. Recent salmon abundance levels in the northern North Pacific Ocean, as indexed by commercial catch, have been among the highest on record, with no indication of declines. While the North Pacific Ocean continues to produce large quantities of Pacific salmon, temporal abundance patterns vary among species and areas. Currently, pink and chum salmon are very abundant overall, chinook and coho salmon are less abundant than they were previously, while sockeye salmon abundance varies among areas. Chum and pink salmon are the most abundant species on the Asian side of the North Pacific; pink, sockeye, and chum salmon are the most abundant species on the North American side. Salmon population responses to climate change have differed among regions. In the Western North Pacific Ocean, generally favourable climate-related marine conditions, expanding hatchery operations, and improving hatchery technologies are all playing roles in increasing the abundance of chum and pink salmon. In the Eastern North Pacific Ocean, climate-related changes are playing a major role in expanding chum and pink salmon populations, and declining populations of coho and chinook salmon.

**25 April, 9:30 (W4-6096)**

## Regional differences in climate factors controlling chum and pink salmon abundance

Masa-aki **Fukuwaka**[1], Toshiki Kaga[2] and Tomonori Azumaya[1]

[1] Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsurakoi, Kushiro 085-0802, Japan
E-mail: fukuwaka@fra.affrc.go.jp
[2] National Salmon Resources Center, Fisheries Research Agency, 2-2 Nakanoshima, Toyohira-ku, Sapporo 062-0922, Japan

Abundance levels of chum and pink salmon have changed in an inter-decadal time scale. Catches of these species were larger in the 1930s and the 1990s-2000s than in other decades in the past. Some studies focused on the relationship between Pacific salmon abundance and basin-scale climate indices. Other studies showed regional co-variations in abundances of individual salmon populations and pointed out the importance of regional-scale process in controlling salmon abundance. Thus, we examined the relationship between climate factors, such as air temperature, precipitation, sea surface temperature, and change rates in coastal catches of chum ($\ln(C_{t+4}/C_t)$) and pink salmon ($\ln(C_{t+2}/C_t)$) in five regions of the Pacific Rim (*i.e.* Japan, Russia, US Northwest and British Columbia, Southeast Alaska, and Western and Central Alaska). Using the correlation analysis adjusting the degree of freedom considering temporal autocorrelation, we found a difference in climate factors, with the strongest effect on change rate in regional salmon catch and the difference in temporal change of salmon catch among regions. Most of these climate factors have been previously reported as a controlling factor of salmon abundance for individual or regional populations. These results suggested that no climate factors or indices control salmon abundance commonly in every region; however, global climate changes can affect regional climate directly and regional salmon abundance indirectly. We conclude that the mechanisms controlling regional salmon abundance are needed to study the forecasting of future conditions of salmon stocks because responses of salmon stocks to global climate changes can be different among regions.

**25 April, 9:50 (W4-6138)**

## Global warming and density-dependent effects on Hokkaido chum salmon

Masahide Kaeriyama, Michio J. Kishi and Hyunju **Seo**

Faculty of Fisheries Sciences, Hokkaido University, 3-1-1 Minato, Hakodate, Hokkaido, 041-8611, Japan. E-mail: salmon@fish.hokudai.ac.jp

We reveal the effects of the regional and larger spatial scales of climatic/oceanic conditions on growth, survival, and population dynamics of Hokkaido chum salmon using path analysis. Variability in growth of chum salmon at age-1 to -4 was estimated based on the back-calculation method using scales of 4-year-old adults returning to the Ishikari River of Hokkaido Island in Japan during 1945-2005. Growth of Hokkaido chum salmon indicated an increase at age-1 and decline at age-2, -3, and -4 since the 1980s. The path analysis results showed that the growth at age-1 in the Okhotsk Sea was directly affected by warmer sea surface temperature (SST) which was strongly caused by the global warming effect. Then, the increased growth at age-1 directly affected the higher survival rate and indirectly the larger population size. In the Bering Sea, subsequently, the enlarged population size directly affected the decreased growth at age-3 and indirectly the smaller fork length of adults, despite no relation between SST, zooplankton biomass, and the growth at age-2 to -4. Therefore, faster growth at age-1 relating to global warming will positively affect the survival rate. In turn, it will lead to a population density-dependent effect on the growth of Hokkaido chum salmon at age-2 to -4 and maturing in the Bering Sea because of limited carrying capacity.

**25 April, 10:10 (W4-6203)**

## Implications of a warming eastern Bering Sea on western Alaska salmon

Ed V. **Farley**, Jr., Lisa B. Eisner, J. Murphy, R. Heintz and Alex Andrews

NOAA, NMFS, AFSC, Ted Stevens Marine Research Institute, 17109 Point Lena Loop Rd., Juneau, AK, 99801, USA. E-mail: ed.farley@noaa.gov

Large scale fisheries and oceanographic surveys along the eastern Bering Sea shelf provide an opportunity to examine how juvenile western Alaska salmon have responded to shifting ecosystem states (warm versus cold). During years with a warm spring and summer sea surface? temperatures, the juvenile salmon growth rate potential is higher, their diets generally consist of age 0 walleye pollock, they are relatively abundant, and are larger when compared to juvenile salmon captured during years with a cold spring and summer sea surface temperatures. However, juvenile salmon stocks that enter the northeastern Bering Sea (Yukon River) display differential early marine mortality during cold years compared to those salmon captured in the southeastern Bering Sea. It is generally agreed that the climate in the Arctic and Bering Sea is warming. A bioenergetics model for juvenile sockeye salmon suggests that increasing sea surface temperatures by 20% during the summer decreased their growth rate potential, particularly during years with already warm summer sea surface temperatures. Recent evidence also suggests that some juvenile salmon species had significantly lower energy density during years with warm sea surface temperatures which may have implications for overwinter survival. These results and other Berin-Aleutian Salmon International Survey (BASIS) data are used to examine whether or not increased warming on the eastern Bering Sea shelf will negatively affect juvenile western Alaska salmon fitness.

**25 April, 10:50 (W4-6381)**

## Phenolgy of high latitude chinook salmon populations

Phillip R. **Mundy**[1] and Dani F. Evenson[2]

[1] Alaska Fisheries Science Center, 17109 Pt Lena Loop Rd., Juneau, AK, 99801, USA. E-mail: phil.mundy@noaa.gov
[2] Alaska Department of Fish and Game, 333 Raspberry Rd., Anchorage, AK, 99518, USA

We report on progress in developing quantitative measures of salmon spawning migrations for comparison to environmental factors in order to understand the effects of climate change on salmon. Timing of annual spawning migrations of salmon in some localities is dependent on the width of an annual time window when temperatures support viability of gametes. Timing of marine exit may be linked to climate and weather through effects on the location and stability of temperature-salinity fronts at the river mouth. Spawning migrations in high latitudes, where the windows of suitable environmental conditions are narrow, may be particularly sensitive to climate change.

During the second half of the 20th century the Yukon River watershed has experienced substantial warming in air temperatures, exhibiting an increase of +5°F relative to the long term average since 1950. The Intergovernmental Committee on Climate Change (IPCC) predicts warming to be particularly acute for continental climates at the latitudes of the Yukon River drainage. Our work describes timing of chinook salmon on the Yukon River delta over the past forty years as an indicator of the effects of climate change on salmon. Our long-term goal is to apply the indicators to understand how salmon might respond to future conditions projected in IPCC scenarios.

**25 April, 11:10 (W4-6218)**

## Climate effects and Oregon coast coho salmon: A multi-ecosystem approach

Thomas C. **Wainwright** and Laurie A. Weitkamp

NOAA Northwest Fisheries Science Center, Newport Field Station, 2032 Southeast OSU Dr., Newport, OR, 97365, USA
E-mail: thomas.wainwright@noaa.gov

Coho salmon (*Oncorhynchus kisutch*) that spawn in the coastal rivers of Oregon, U.S.A, are listed as 'threatened' under the U.S. Endangered Species Act. We present an assessment of the effects of climate change on sustainability of this population group. Four distinct ecosystems are important to different life-history stages of coho salmon: terrestrial forests, freshwater rivers and lakes, estuaries, and the North Pacific Ocean. Each of these systems is affected by multiple aspects of climate change, resulting in a complex web of pathways influencing sustainability. While climate models provide quantitative estimates of likely trends for some of the physical changes, we lack sufficient understanding of the biological response to reliably quantify the effects on salmon populations and extinction risk. For this reason, our analysis is qualitative: we summarize likely trends in climate, identify the pathways by which those trends are likely to affect salmon, and assess the likely direction and rough magnitude of response by life history stage. While we find some positive effects, negative effects predominate at every stage. We then consider the cumulative impacts across the coho salmon life-cycle and across multiple generations. Because these effects are multiplicative, small effects at individual life stages can result in large changes in the overall dynamics of populations, so we expect a strong overall negative effect. Similarly, cumulative uncertainties for life-stage-specific effects will lead to large uncertainties in future sustainability, and these uncertainties will contribute to increasing risk. Without strong conservation efforts, the future does not look very bright for these fish.

**25 April, 11:30 (W4-6245)**

## Adaptation and persistence of Pacific salmon facing climate change: An individual-based modeling analysis

Thomas E. **Reed**[1,2], Robin S. Waples[2], Daniel E. Schindler[1], Eli Meir[3] and Nathan J. Mantua[1]

1 School of Aquatic and Fishery Sciences, University of Washington, P.O. Box 355020, Seattle, WA, USA. E-mail: tomreed@uw.edu
2 National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA, 98112, USA
3 SimBiotic Software, 148 Grandview Court, Ithaca, NY, 14850, USA

Climate change impacts on Pacific salmon have far-reaching ecological and economic consequences, given their pivotal role in freshwater, terrestrial and marine ecosystems and their importance to human communities around the Pacific Rim. Predicting these impacts is complicated by obstacles to downscaling coarse-grained climate models to salmon watersheds, resolving uncertainties in climate change scenarios, and understanding mechanistic responses of salmon and their habitats to environmental change. Timing traits are likely to face strong, potentially conflicting selection pressures as the optimal periods for migration, spawning, emergence and growth shift with abiotic and biotic changes in freshwater and marine environments. We developed an individual-based ecogenetic model to explore potential demographic consequences of plastic and evolutionary responses in migration timing (timing of ocean entry for smolts, and river entry for adults) for different salmon life histories, under a range of climate change scenarios. We characterized climate-induced selection on timing traits for a generalized coho (*Oncorhynchus kisutch*) life history, using generic functions derived from the literature. We then applied this model to a number of different US and Canadian watersheds, for which downscaled (50 year) projections of changes in temperature and flow profiles, under a range of global climate change scenarios, were available. Preliminary results suggest that evolutionary and plastic responses might facilitate persistence in some

populations and regions, whereas extinction might be unavoidable for others. Our model provides a flexible tool to explore how evolutionary and ecological processes interactively affect salmon persistence in a changing climate, ultimately informing management actions.

**25 April, 11:50 (W4-6087)**

## The Salmon Monitoring Advisor: A hierarchical web site to help design and implement salmon monitoring programs

Randall M. **Peterman**[1], Peter B. Adams[2], Brigitte Dorner[1,3], Douglas L. Drake[4], Harold J. Geiger[5], Kendra Holt[1,6], Chris Jordan[7], David P. Larsen[8], Steven A. Leider[9], Richard H. Lincoln[10], Anthony R. Olsen[11], Charles K. Parken[6], Jeffrey D. Rodgers[12] and Shaun Walbridge[13]

1 School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC, V5A 1S6, Canada. E-mail: peterman@sfu.ca
2 Southwest Fisheries Science Center, National Marine Fisheries Service, Santa Cruz, CA, USA
3 General Delivery, Lasqueti Island, BC, V0R 2J0, Canada
4 Oregon Department of Environmental Quality, 2020 SW 4th Ave., Portland, OR, 97201, USA
5 St. Hubert Research Group, 222 Seward St., Suite 205, Juneau, AK, 99801, USA
6 Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada
7 NOAA Fisheries, c/o U.S. Environmental Protection Agency, 200 SW 35th St., Corvallis, OR, 97333, USA
8 Pacific States Marine Fisheries Commission, c/o U.S. Environmental Protection Agency, 200 SW 35th St., Corvallis, OR, 97333, USA
9 Governor's Salmon Recovery Office, Olympia, WA, USA
10 State of the Salmon, 721 NW Ninth Ave., Suite 300, Portland, OR, 97209, USA
11 Western Ecology Division, National Health and Environmental Effects Laboratory, U. S. Environmental Protection Agency, 200 SW 35th St., Corvallis, OR, 97333, USA
12 Oregon Department of Fish and Wildlife, 28655 Hwy 34, Corvallis, OR, 97333, USA
13 National Center for Ecological Analysis and Synthesis, 735 State St., Suite 300, Santa Barbara, CA, 93101, USA

Salmon managers, scientists, and non-governmental organizations face substantial challenges designing cost-effective monitoring programs to assess both status and time trends in abundance, productivity, spatial structure, and diversity of salmon populations. We are currently developing a web-accessible knowledge base called the "Salmon Monitoring Advisor" to help such people choose designs that (1) reliably estimate changes in salmon indicators, and (2) estimate the relative contribution of climate-driven mechanisms to those observed changes (compared to changes caused by other factors). This web site provides a systematic, structured framework to help users develop clear goals and objectives, as well as design and implement salmon monitoring programs that are reliable, informative, and cost-effective. The site is accessible in a hierarchical manner to reflect diverse audiences, including (1) scientists who design monitoring programs and/or analyze the resulting data, (2) technical staff who implement monitoring designs in the field, (3) people involved in providing funding for monitoring programs, and (4) managers and decision makers in government agencies or in local or regional salmon conservation organizations. This web site is named "Salmon Monitoring Advisor" because it provides advice and guidelines to help users work through the essential steps involved in designing monitoring programs to meet stated objectives, and provides pros and cons of different designs, rather than being prescriptive about which design best meets a particular monitoring objective. The web site uses seven sequential steps to guide monitoring design and implementation and provides extensive explanations and real-world examples for each step.

**25 April, 12:10 (W4-6222)**

## Developing salmon management responses to climate impacts at the watershed scale

Larry **Wasserman**

Swinomish Indian Tribal Community, 11430 Moorage Way, LaConner, WA, 98257, USA. E-mail: lwasserman@skagitcoop.org

While the effects of global warming are most frequently modeled at a regional scale, management decisions affecting salmon are often made at the watershed level by tribal, local and state governments. Changes in hydrology, sediment transport, water quality and sea level associated with climate change have the ability to significantly alter freshwater survival of anadromous salmonids, a resource upon which Native American communities depend. The Skagit Climate Science Consortium (SCSC) was established in response to the need to provide a watershed level of analysis of processes influencing salmon survival within the Skagit River basin. The Skagit River basin is the third largest river in the western United States and home to six species of *Oncorhynchus*. SCSC scientists from Federal, Tribal and city governments and two universities are coordinating research efforts at a basin scale to make predictions of the implications of climate change on the Skagit watershed that will help to inform decisions associated with changes in hydropower operations and flood damage reduction efforts, salmon restoration initiatives, and instream flow protection strategies, to name a few. Efforts are underway to link modeling efforts directed at impacts on glaciers in the headwaters, changes in basin hydrology and sedimentation, and sea level rise. This paper will discuss an approach to link scientific investigations among diverse disciplines with local decision making needs associated with the protection of freshwater ecosystems upon which salmon resources depend.

# W4 Posters

### W4-6048

## Atlantic salmon population dynamics under scenarios of climate change: An individual-based demogenetic approach

Cyril **Piou** and Etienne Prévost

INRA, UMR INRA-UPPA ECOBIOP, Pôle d'Hydrobiologie, Quartier Ibarron, St-Pée-sur-Nivelle, 64310, France
Email: Cyril.Piou@st-pee.inra.fr

Atlantic salmon, *Salmo salar*, populations are prone to the influence of climate change both in their river and oceanic phases. Increase in river temperature and flow variability could modify growth conditions and secondarily marine survival. Marine growth and survival conditions have been hypothesized as affected by past climate changes. The current balances between alternative life histories could be altered. We integrated a cohesive amount of knowledge on *S. salar* biology representing the processes of growth, survival, life history decisions and reproduction in an individual-based demogenetic model to simulate small Western European populations. Migration and maturation processes are represented as genetically heritable probabilistic reaction norms in order to incorporate the influence of life history evolution on population dynamics. We used this model to assess the changes in life history balances (*e.g.* river residence *vs.* anadromy; one winter *vs.* multiple winters at sea) in relation to three synergetic influences: 1) differential exploitation rates of the different age class; 2) river climate change; 3) marine environmental change. We find that as long as the stressors are not lethal for the population, the evolution of marine life history traits is mainly driven by selective pressures from exploitation rates. However, marine conditions and flow regimes are also of utmost importance in controlling stocks abundances, in shaping river residence proportions and in evolution toward shorter life cycles. We discuss these findings in the light of recent field observations of modifications in European populations and the future of Southern *vs.* Northern Europe populations.

### W4-6133

## Long-term changes in biological characteristics and abundance of Atlantic salmon juveniles and adults from important Kola Peninsula rivers (Russian Federation)

Sergey **Prusov**, Boris Prischepa, Elena Samoylova and Svetlana Krylova

Knipovitch Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovitch St., Murmansk, 183763, Russia
E-mail: prusov@pinro.ru

The life history of Atlantic salmon (*Salmo salar* L.) includes long periods of life in salt- and freshwater environments, with salmon being exposed to the impact of a complex of factors of different origins. Studies have shown that the number of salmon returning to rivers is dependent upon the smolt production and marine exploitation rates as well as the variability in ocean conditions that also influence the survival, growth and subsequent sea-age at maturation of salmon. To date, the important Kola Peninsula salmon rivers, which have an extensive and mostly pristine habitat for Atlantic salmon, remain among a rare group of stocks that have been spared from being categorized by continued long-term declines in salmon abundance. The recreational salmon fishery, developed in the region on the catch-and-release principle, today is seen as one of the highest quality and most prestigious in the North Atlantic. However, the climate-driven changes in freshwater environment (*e.g.,* temperature and water level changes) can have a dramatic impact on salmon juveniles and adults. The long-term monitoring programmes have identified the upward trend in water temperature of salmon rivers. Even slight alterations can be significant for juveniles, which stay in the northernmost rivers for up to seven years, as well as for autumn-run adults, which spawn in the rivers one year after arrival. This study aims to conduct a comparative analysis of long-term changes in biological characteristics and abundance of Atlantic salmon juvenile and adults of several Kola Peninsula salmon stocks.

**W4-6144**

## Effects of coastal seawater temperature on the return rate of hatchery-reared chum salmon in Hokkaido and recent shifts in coastal environmental conditions and release of juveniles

Yasuyuki **Miyakoshi**[1], Mitsuhiro Nagata[1], Makoto Fujiwara[1] and Sei-ichi Saitoh[2]

[1] Hokkaido Fish Hatchery, Kitakashiwagi 3-373, Eniwa, Hokkaido, 061-1433, Japan. E-mail: miyakoshiy@fishexp.pref.hokkaido.jp
[2] Laboratory of Marine Environment and Resource Sensing, Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minato-cho, Hakodate, Hokkaido, 041-8611, Japan

In Hokkaido, northern Japan, chum salmon stocks are reproduced by intensive hatchery programs; approximately one billion juvenile chum salmon are released from hatcheries in spring. The number of chum salmon returning to Hokkaido has increased since the 1970s and are at a historically high level after the 1990s. However, a large difference in the return rates of hatchery-reared juveniles has been observed among regions in Hokkaido. The early marine phase is thought to be a critical period for hatchery-reared chum salmon when mortality is highly variable. To understand the effects of coastal environmental conditions on the survival of chum salmon, we analyzed the relationship between coastal sea surface temperature (SST) and the return rate of chum salmon stocked along each coast of Hokkaido from 1985 to 2002. Significant effects are observed between SST and the return rate in eastern Hokkaido where the inter-annual variation of SST is large. The results suggest that the SST in the coastal areas should be an important factor affecting the survival of released chum salmon, while other factors, *e.g.* release timing and fish size, may affect the survival. The timing and duration of optimum coastal temperatures for residence of juvenile chum salmon differ among coastal regions and have been shifted gradually in the last few decades. Release timings also have been shifted and the sizes of juveniles have been improved. Recent shifts in environment conditions and release of hatchery-reared juveniles should affect the survival of released fish differently in each region of Hokkaido.

**W4-6180**

## Archeological evidence implies that global warming will shift Japanese chum salmon distributions northward

Yukimasa **Ishida**[1], Hiroyasu Adachi[1], Isao Yagisawa[1], Kazuaki Tadokoro[1] and Harold J. Geiger[2]

[1] Tohoku National Fisheries Research Institute, 3-27-5 Shinhama-cho, Shiogama City, Miyagi Prefecture, 985-0001, Japan
E-mail: ishiday@fra.affrc.go.jp
[2] St. Hubert Research Group, 222 Seward, Suite 205, Juneau, AK, 99801, USA

Archeological evidence from Hokkaido and the Tohoku Region in Japan showed that humans utilized Pacific salmon (*Oncorhynchus* spp.) there at least 6,000 years ago. Approximately 5,000-6,000 years before the present, what is now called the Kushiro Wetland, on the island of Hokkaido, was the saltwater-covered Paleo Kushiro Bay. Based on the molluscan fossil fauna, the seawater temperature in Paleo Kushiro Bay was about 5°C warmer than it is currently. The oldest salmon remains in the northern part of the Tohoku Region, on the island of Honshu, date to 6,000-8,000 years ago. Salmon remains were found in Miyako, dating to 5,000-6,000 years ago; in Oofunato, dating to 4,000-5,000 years ago; in Rikuzentakada, dating to 3,000-4,000 years ago; and in Naruse in Senda Bay, dating to 2,000-3,000 years ago. These shifts in salmon remains, from north to south, appear to reflect the change in salmon distribution coincident with decreasing temperatures after the Jomon Marine Transgression, which peaked 6,000 years ago. Based on these observations of the past, we expect that global warming will move the southern limit of salmon distribution northward. We also expect this warming to reduce salmon production in Japan, as sea surface temperatures and other conditions become similar those that existed 5,000-6,000 years ago. We recommend adaptive measures to mitigate future global warming. Such measures might include favoring stock enhancement with late-run stocks, allowing more natural spawning, placing a greater emphasis on hatchery feeding programs, and adaptively changing the number of juvenile salmon released from hatcheries.

**W4-6268**

## Climate, growth, and population dynamics of western Alaska Chinook and coho salmon

Gregory T. Ruggerone[1], Beverly A. Agler[2] and Jennifer L. **Nielsen**[3]

[1] Natural Resources Consultants, Inc., 4039 21st Ave. West, Suite 404, Seattle, WA, 98199, USA. E-mail: GRuggerone@nrccorp.com
[2] Alaska Department of Fish and Game, Division of Commercial Fisheries, Mark, Tag and Age Lab, 10107 Bentwood Place, Juneau, AK, 99801, USA
[3] Alaska Science Center, U.S. Geological Survey, 4210 University Dr., Anchorage, AK, 99508, USA

Salmon in western Alaska have undergone significant shifts in abundance during the past 50 years. Abundances of Chinook and coho salmon were relatively low during the 1960s to mid-1970s, high from mid-1970s to mid-1990s, and low from late 1990s to late 2000s. These shifts in abundance corresponded with the 1977 ocean regime shift and the 1997/1998 El Niño. We examined ocean growth patterns of salmon in relation to climate and other variables using measurements of salmon scales during the past five decades. Chinook salmon scale growth during each year at sea was not related to climate shifts, but their growth was related to their previous growth history and to pink salmon. Growth of coho salmon during their first season at sea increased during the late 1970s and remained relatively high until the late 1990s. Coho salmon growth was correlated with sea surface temperature and pink salmon but spawning biomass of pollock, whose larvae provide key prey, explained more scale growth variability. Coho abundance was positively correlated with first year growth at sea and with the index of larval pollock. However, physical variables, such as SST, PDO and Aleutian Low, did not explain the model residuals, which exhibited strong shifts associated with the 1977 and 1989 climate events. In contrast to western Alaska sockeye salmon, in which early marine growth explained much of their variability in abundance, growth of coho and Chinook salmon did not fully explain the large shifts in their abundance that were associated with climate events.

# W5 Invited Presentations

**25 April, 9:15 (W5-6152)**

## Identification of global marine hotspots: Sentinels for change and vanguards for adaptation

Alistair J. **Hobday**[1] and Gretta Pecl[2,3]

[1] Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart, 7001, Australia
E-mail: alistair.hobday@csiro.au
[2] Climate Change Theme Area, Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Private Bag 49, Hobart, Tasmania, 7001, Australia
[3] Adaptation Research Network for Marine Biodiversity and Resources

Marine natural resources, such as fisheries, provide significant social and economic benefits globally, and early warning of changes in resource availability is required to minimise social tensions (*e.g.* increased poverty and changes in resource allocation) and societal costs (*e.g.* income redistribution and government restructuring). Additionally, prior knowledge of how and when resources may alter will also facilitate the development, application and evaluation of adaptation options for fisheries. We identify the global warming hotspots over the last 50 years using historical datasets, and predict their location for the next 50 years based on an ensemble of AR4 global climate models. Examination of hotspots provides us with the first opportunities to detect the nature and pace of climate change induced impacts on our marine ecosystems, separate the impacts of synergistic stressors like climate and fishing, and also offers the strongest prospect for validating species or ecosystem model projections against reality. With sufficient interdisciplinary research and information, these hotspots will also provide the first opportunity for evaluation of adaptation options in fishery systems. A network of scientists working in global marine hotspots, where information is integrated and synthesized, contrasted and compared across locations, can best address the challenges of climate change. Collaboration at a global scale is necessary to develop knowledge for managers to make decisions and for increased community understanding of the need for these decisions, including increased confidence in the models and adaptation options being proposed.

**25 April, 9:30 (W5-6312)**

## Climate driven changes in marine assemblages in SE Australia: A southern hemisphere 'hotspot'

Stewart **Frusher**[1], Gretta Pecl[1], Alistair J. Hobday[2], Craig Johnson[1,3] and Zoe Doubleday[1]

[1] Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Private Bag 49, Hobart, Tasmania, 7001, Australia
E-mail: stewart.frusher@utas.edu.au
[2] CSIRO Marine and Atmospheric Research, Castray Esplanade, Hobart, Tasmania, 7001, Australia
[3] School of Zoology, University of Tasmania, Private Bag 5, Hobart, Tasmania, 7001, Australia

The waters adjacent to the south-eastern region of Australia have warmed at a rate 3.8 times the global average over the last decades and are predicted to continue warming at a relatively rapid rate. These changes are a result of the extension and strengthening of the East Australian Current which carries warm and nutrient poor tropical waters south along the east coast of Australia. Concomitant with the increased southern penetration of this current is a change in the productivity of inshore regions due to changes in growth rates of coastal species and their recruitment dynamics; southern (poleward) range extensions of both invertebrate and vertebrates with at least several dozen fish species being identified as either new records or newly established in southern areas; changes in the phenology of commercially important species and changes in species interactions. Recent increases in the abundance of the invasive sea urchin *Centrosetphanus rodgersii*, a voracious grazer of seaweeds, is of particular concern as it overgrazes the seaweed canopy resulting in urchin 'barrens'. Increases in *Noctiluca* blooms have also been recorded, as have a decline in giant kelp. Combined, these changes are resulting in impacts on the structure and functioning of marine ecosystems with ramifications for marine biodiversity, fisheries and aquaculture. The south-eastern region of Australia generates 50% of Australia's fisheries production, possesses a large proportion of endemic species (60%) and there is no land mass further south for species that find themselves 'in hot water'.

**25 April, 9:45 (W5-6408)**

## The Benguela Current Large Marine Ecosystem

Larry Hutchings[1], Carl van der Lingen[1], Chris Reason[2], Frank Shillington[2], Andy Cockcroft[1], Warren Potts[3], Romina Novo-Henriques[3], Paul Shaw[3] and Warwick **Sauer**[4]

[1] Department of Marine and Coastal Management, Private Bag X2, Roggebaai, 8012, South Africa
[2] University of Cape Town, Private Bag, Rondebosch, South Africa
[3] School of Biological Sciences, Royal Holloway University of London, Egham TW20 0EX, UK
[4] P.O. Box 94, Grahamstown, Rhodes University, 6140, South Africa. E-mail: W.Sauer@ru.ac.za

The Benguela system is one of the major eastern boundary upwelling systems of the world, together with the Humboldt, Canary and California Current ecosystems. The Benguela Ecosystem is inherently highly productive, complex and variable, and it is extremely difficult to separate the climate change "signal" from "noise". We have comprehensive data sets stretching back about 50 years and long term trends and cycles are beginning to emerge from data and models. It is clear that conditions in the large ocean basins surrounding southern Africa play an important role in changing not only the marine resources in the coastal regions, but terrestrial rainfall and weather patterns as well over the entire region. One of the strongest trends in the data has been a warming at the northern and southern boundaries of the Benguela system. The northern warming has occurred across the boundary, while the southern Boundary has warmed just south of the Agulhas Bank, with cooling in the inshore areas of the Agulhas Bank and southern Benguela, increasing the gradients across the southern boundary region. There has been an increased frequency of "warm events" at the Angola-Namibia border in the past decade, and a persistent change in the onset of seasonal warming in the north, with the potential to effect distribution and productivity of local inshore linefish species, and potential consequences for increased hypoxia (low oxygen water) on the Namibian shelf. In this respect, it is thought that a major low oxygen event off Namibia in the 1990's had a severe and longlasting impact on the hake stocks, which have not recovered despite stringent management actions from government agencies. This decline in oxygen waters appears also to have a deleterious effect on rock lobster, which have increased in walkouts in the past four decades and a southwards and eastward shift in distribution. Viewing the system as a whole, there has been persistent decadal variability in the BCLME, and it is not clear that these changes are linked exclusively to climate change, or to inherent natural long term cycles. Future research and monitoring efforts need to focus on a much broader approach in space and time, including global changes and palaeo-oceanographic time scales. Not only is this important for future marine ecosystem management, but it is likely to underpin future seasonal and longer term weather and climate change forecasts in the region.

**25 April, 10:00 (W5-6321)**

## Catastrophic changes to inshore benthic communities following oceanographic warming events in the Galapagos archipelago

Graham **Edgar** [1] and Stuart Banks[2]

[1] Institute of Marine and Antarctic Studies, Private Bag 49, University of Tasmania, Hobart, Tasmania, 7001, Australia
E-mail: g.edgar@utas.edu.au
[2] Charles Darwin Foundation, Puerto Ayora, Galapagos, Ecuador

Habitat types and ecological communities across the Galapagos Marine Reserve have been greatly affected by extreme thermal anomalies over the past 30 years, with greatest changes detected for populations of many species at the time of the 1982/83 El Niño. Despite the regular occurrence of El Niño in the region for millennia, inshore reef communities possess a low apparent level of resilience to extreme warming events, as indicated by little recovery towards pre-existing conditions since 1983. Communities associated with upwelling regions and coral reefs were both disproportionately affected by the 1982/83 El Niño, primarily through associated overgrazing of macroalgae and corals by sea urchins and a huge expansion in the total area occupied by urchin barrens. The removal of large lobster and fish predators by artisanal fishing has probably magnified impacts of ENSO events through a cascade of indirect effects involving urchins. Populations of many macroalgae, invertebrates, fishes, turtles, seabirds and marine mammals across the Galapagos region are predicted to increasingly decline through the next century as a consequence of climate change, putting many endemic species at risk of extinction.

**25 April, 10:15 (W5-6307)**

## Biological responses to recent climate variability on the eastern Bering Sea shelf

Franz J. **Mueter**

School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, 99801, USA. E-mail: fmueter@alaska.edu

Temperature variability on the eastern Bering Sea shelf can be decomposed into high-frequency interannual variability, decadal-scale variability, and a long-term warming trend. These sources of variability interacted to produce the well documented regime shift from cold to warm conditions in 1976/77. Continued warming associated with a large-scale climate signal led to some of the warmest temperatures on record in the early 2000s, but more recent years have seen a return to extensive ice conditions and the coldest bottom temperatures since the early 1970s. Warming associated with the 1976/77 shift produced favorable conditions for groundfish and sockeye salmon and appeared to be associated with a general increase in productivity in the region. In spite of high variability, generally favorable conditions for many groundfish and salmon stocks persisted for several decades. However, the unprecedented warming in the early 2000s was associated with very poor survival of the pelagic juveniles of two abundant and commercially important gadid species, walleye pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*). Researchers are just beginning to unravel the potential causes of these poor year classes. Other changes associated with warming in the eastern Bering Sea include marked northward shifts in the distribution of numerous groundfish species and an associated shift in the ecotone between Arctic and subarctic communities. In spite of a return to very cold conditions in recent years, many biological indicators show a persistent directional trend. This suggests that the long-term warming trend may have become a dominant driver of biological variability in the region.

**25 April, 11:00 (W5-6306)**

## Overview of climate change effects in British Columbia marine ecosystems

Thomas A. **Okey**[1,2,3], Alvaro Montenegro[4], Veronica Lo[5], Sabine Jessen[5] and Hussein Alidina[6]

1 West Coast Vancouver Island Aquatic Management Board, 3-4310 10th Ave., Port Alberni, BC, V9Y 4X4, Canada
E-mail: Thomas.Okey@gmail.com
2 University of Victoria School of Environmental Studies, Victoria, BC, V8W 2Y2, Canada
3 Conservation Science Institute, http://csi-global.org
4 Earth Sciences Dept., St. Francis Xavier University, 1 West St., Antigonish, NS, B2G 2W5, Canada
5 Canadian Parks and Wilderness Society - BC Chapter, 410 - 698 Seymour St., Vancouver, BC, V6B 3K6, Canada
6 World Wildlife Fund Canada, 1588-409 Granville St., Vancouver, BC, V6C 1T2, Canada

British Columbia's highly complex and dynamic geomorphology and oceanography, and mostly remote geography, hinders general understandings of climate change impacts. Its northern portion—the Pacific North Coast Integrated Management Area (PNCIMA)—coincides with the transition zone between the Alaskan Coastal Downwelling Zone and the California Current Coastal Upwelling Zone. This transition zone shifts with oceanographic cycles, thereby theoretically shaping a responsive and resilient marine biota. However, a suite of physical oceanographic changes have been documented in British Columbia marine and aquatic ecosystems on time scales of 50 to 100 years, and projections indicate continued directional changes. A number of biological changes have also been observed, and these changes likely represent only the most conspicuous indicators of broader effects. The biological changes and phenomena observed in relation to climate and oceanographic variability in the northeast Pacific provide some insights into future long-term biological changes, but their character, nature, and magnitude will likely differ from variability-related changes. Knowledge about commercially-important species and other well-known species allows for inference about distributional shifts, but attempts to project indirect and complex climate change effects on the assemblage and structure of these biological communities are just now emerging. The government of Canada is undertaking integrated management planning in its Large Ocean Management Areas, including the PNCIMA, and Canadian provinces are responsible for marine resources management in their coastal zones. However, attention to climate change impacts is conspicuously lacking from assessments and management. Broadly integrated frameworks and approaches to science and management (*e.g.* of anthropogenic stressors) are needed.

**25 April, 11:15 (W5-6416)**

## Rapid ecological change in the Northeast Atlantic climate change hotspot

Nicholas K. **Dulvy**[1], Doug J. Beare[2], Julia L. Blanchard[3], Jan G. Hiddink[4], Simon Jennings[5], Brian J. MacKenzie[6] and Allison L. Perry[7]

1 Earth to Ocean Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, BC, V5A 1S6, Canada E-mail: dulvy@sfu.ca
2 Fisheries Research Services, Marine Laboratory, P.O. Box 101, Victoria Rd., Torry, Aberdeen, AB11 9DB, UK
3 Division of Biology, Imperial College London, Silwood Park Campus, Buckhurst Rd., Ascot , SL5 7PY, UK
4 School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey LL59 5AB, UK
5 Centre for Environment Fisheries and Aquaculture Sciences, Pakefield Rd., Lowestoft, NR33 0HT, UK
6 Danish Institute for Fisheries Research, Department of Marine Ecology and Aquaculture, Kavalergarden 6, 2920 Charlottenlund, Denmark
7 The WorldFish Center, P.O. Box 500 GPO, 10670 Penang, Malaysia

The shelf seas of the North Atlantic Ocean, particularly the North Sea, represent one of the climate change hotspots of the world. Sea surface temperatures of Northeast Atlantic and UK coastal waters have warmed by 0·2–0·6°C decade$^{-1}$ over the past 30 years. These surface increases belie greater increases in winter bottom temperature of 1·6°C over 25 years, including an almost 1°C step change in temperature between 1988-89. Summer temperatures have risen 2-5 times faster than other seasons, mainly due to the increased frequency of extremely warm years. Temperatures in the North Sea and adjacent Baltic Sea now exceed any temperature recorded since instrumental records began in 1861 and 1880, respectively. Resulting ecological changes in the fish assemblages have been rapid.

Fishes are following the physics of temperature, tracking isotherms northward and downward. The poleward deepening of isotherms has influenced the availability of thermal habitat, leading to a reduction in the areal extent of cold thermal habitat and an increase in the extent of warmer isotherms. Fishes with geographic range boundaries in the North Sea are shifting poleward at rates four times greater than recorded for many terrestrial taxa. Species with warmer thermal preferences and southern biogeographic affinities are expanding their geographic ranges into NE Atlantic shelf habitats and fishes with boreal cooler thermal preferences are contracting northward. Fish depths are responding to warming; the whole North Sea fish assemblage closely tracks annual variations in water temperatures and is deepening at a rate of 3.6 m decade$^{-1}$. In addition to local distributional changes, the North Sea and surrounding waters are experiencing waves of invasion by southerly species, such as red mullet, anchovy and pilchard. Both invasions and local distributional shifts are resulting in increased turnover and elevated species richness in the North Sea.

Aside from changes in distribution, local turnover and species richness, climate impacts are manifest at the ecosystem scale. Climate variability influences the size structure of Celtic Sea fish assemblages. Increased temperatures have been associated with steeper size spectra slopes, which results from more small bodied individuals and species relative to large-bodied individuals and species, even after accounting for fishing pressure.

**25 April, 11:30 (W5-6341)**

## Aquaculture and climate change in the coastal zone of Vietnam

Nguyen Huu **Ninh**

Center for Environment Research, Education and Development (CERED), 279/24 Giang Vo, Hanoi, Vietnam. E-mail: cered@vnn.vn

Economic development activities in the coastal zone are abundant and give the local people many benefits of which fishery and aquaculture, particularly shrimp farming, is the major sector. Recently aquacultural activities have been flourishing on the coast, and shrimp and clam farming have developed over the past 20 years but not all of the aquacultural activities have been successful. One reason identified by scientists pertains to farmers' lack of knowledge of ecological conflicts and climate change.

The issue will become more critical is future years as global environmental change places increasing pressure on the coastal zone. The natural ecosystem often destroyed to develop aquaculture is the mangrove forest. As well as providing a wide range of ecological services and extractive resources, mangroves play a major role in

protecting the inward coastal zone against flooding caused by the tropical storms that regularly strike the coastline of Vietnam. The destruction of the mangrove ecosystem increases vulnerability in the present-day and heightens the risk of climate change impacts.

Thus the question is to find the most appropriate aquacultural land management practices which balance economic and environmental benefits both in the present-day and in future years. The objective of this study is to assess the costs and benefits of different patterns of land use for aquaculture as well as to consider the income of people involved in collecting marine products from the mudflats. From these findings, conclusions may emerge regarding the possibility of developing a feasible plan for sustainable development in regard to climate change.

**25 April, 11:45 (W5-6406)**

## Impact of climate change on coastal fishery resources of Taiwan

Kuo-Tien Lee and Hsueh-Jung **Lu**

Environmental Biology and Fisheries Science, National Taiwan Ocean University, Taiwan, 2 Pei-Ning Rd., Keelung, Taiwan, ROC
E-mail: tienlee@ntou.edu.tw; hjlu@ntou.edu.tw

Average sea surface temperature rise during 1980~2008 in the waters adjacent to Pacific, East China Sea continent and Taiwan Strait were 0.65°C, 0.71°C and 0.75°C, which indicates a trend of diminishing China Coastal Current and enhancement of the Kuroshio Current. The observed impacts from such a change on coastal capture fisheries includes species regime shift, ecosystem structure vulnerability and displacement of fishing grounds. The warming of sea surface temperature has caused a reduction of winter migratory species year after year and accelerated the change of ecological structures. The problem that marine ecosystem and fisheries has to face is the expansion of fish stocks from south and withdrawal of fish stocks from the north. In addition, under pressures from human's fishing activities for several decades, the large fishes at high trophic levels have decreased and small pelagic fishes have increased at the same time. As the inter-annual fluctuations of small pelagic fishes were much higher than those of larger sized or longer lived species, the structure of the food (fish) pyramid in coastal waters would be weakened even more. Future impacts from climate change were assessed using surface temperature provided by Global Change Research Center (GCRC). The results of all scenarios by all models showed that most of the fish will decrease especially those that migrate with the China Coastal Current, and only warm-water fish species may increase. The short-, mid- and long-term warming may lead to a 5-50% decrease in catch for those currently winter migratory species, which means a considerable portion of species will disappear. Traditional fishery management measures would not be able to adapt to the problems caused by climate change. Under such circumstances, traditional fishery management tools are not enough. More external precautionary and adaptive measures need to be introduced to reduce impact and risk.

**25 April, 12:00**

## South China Sea

Wang **Hui**

Abstract N/A

**25 April, 12:15 (W5-6407)**

## Vulnerability to ocean warming in the Mozambique channel region

Lucy Scott[1] and Warwick **Sauer**[2]

[1] UNDP GEF Agulhas and Somali Currents Large Marine Ecosystem (ASCLME) Project, ASCLME House, 18 Somerset St., Grahamstown, 6140, South Africa. E-mail: lucy.scott@asclme.org
[2] Department of Ichthyology and Fisheries Science, Rhodes University, P.O. Box 94, Grahamstown, 6140, South Africa E-mail: W.Sauer@ru.ac.za

African countries are among the most vulnerable to the effects of climate change due to a combination of environmental risk factors, low institutional capacity and high reliance on natural resources. The Mozambique channel region has been identified as one of the global hotspots of ocean warming, and its marine and coastal ecosystems support large human populations that are highly dependent on natural resources. A warming trend in the Western Indian Ocean (WIO) has been observed since 1976 with notable warming events having lead to long-term damage to marine ecosystems. Coral bleaching caused by high ocean temperatures in 1998 resulted in up to 90% coral decline in the Seychelles. Besides direct loss of corals, it negatively affected fisheries productivity in a region where most of the marine fisheries already show signs of overexploitation. While reefs have recovered to varying extents, their structure and communities have changed considerably in certain areas. The impacts of the 1997-1998 El Niño event also had a dramatic impact on the tuna fishery in the WIO. Besides the direct effect on marine habitats, the region experiences seasonal cyclones and heavy rain storm surges, which inundate coastal areas and cause erosion; the frequency and intensity of which are projected to increase with an increase in sea surface temperature. Threats posed by global change in general, and ocean warming in particular, need to be better understood to assist the countries and communities of the region to protect critical areas as well as to adapt and cope with these impacts.

**25 April, 14:00 (W5-6404)**

## The Japan Sea hotspot: Impacts of warming on bio-productivity and fisheries resources

Yury I. **Zuenko**

Japan Sea and North-West Pacific Oceanography, Pacific Research Institute of Fisheries and Oceanography (TINRO-Center), 4 Shevchenko Alley, Vladivostok, Primorsky Kray, 690950, Russia. E-mail: zuenko_yury@hotmail.com

Large-scale changes of oceanographic conditions in the Japan Sea are considered. A trend of water warming, in particular in winter (up to 0.4°/decade at the sea surface), and weakening of convective mixing have been observed in the recent decades, caused mainly by a tendency of the winter monsoon to weaken. Significant decadal fluctuations of water temperature are observed, non-coherent in different seasons, and recently winter warming has ceased because of a cooling phase in winter. The warming tendency is generally unfavorable for water productivity as nutrient influx into the photic layer decreases under conditions of weak convection. However, phytoplankton abundance is determined by other factors as well and doesn't have any significant trend. In contrast, zooplankton abundance has a trend of increasing because a warmer environment improves conditions for reproduction. The growing food base provides for growth of mass planktivore populations of subtropic nekton (japanese common squid, mackerels, tunas, yellowtail); moreover, their available habitats are expanding because of water warming. This expansion causes degradation of mass boreal species of nekton, as walleye pollock and saffron cod. The most important fish species, japanese sardine, has a low abundance in the last two decades but blooms are possible in conditions of both cooling and warming, so recovery of this stock is expected. The process of warming in the Japan Sea does not lead to exhaustion of resources for commercial fisheries in this region but it does cause significant changes in the structure of the catch that demands some reconstruction in the fishery techniques and economics.

**25 April, 14:15 (W5-6405)**

## Oceanography and biological production off South Brazil and Urugay

José H. **Muelbert**

Instituto de Oceanografia, Universidade Federal do Rio Grande, Rio Grande, Brazil. E-mail: docjhm@furg.br

Ocean waters of South Brazil and Uruguay are marked by a complex oceanographic setting and very important fisheries. Strong influence of continental runoff, due to the Rio de la Plata and Patos Lagoon, decreases salinity in coastal shelf waters. Intrusion of sub-antarctic waters contribute to a decrease in local temperature and nutrient enhancement. The presence of the Brazil Current and its encounter with the Malvinas Current generates the Brazil Malvinas Confluence that represents an unique scenario for heat exchange and formation of the South Atlantic Central Water (SACW). The interaction of this oceanographic setting combined with meteorological forcing influences biological and fisheries production in the region. Shrimp catches and larval fish recruitment in the Patos Lagoon Estuary are controlled by extreme precipitation changes due to ENSO. Input of nutrient rich freshwater from the estuaries into the coastal region enhances stratification and formation of frontal regions with increases in biological production. Upwelling of rich sub-antarctic waters favours primary production with further implications for secondary production. The interplay of these different agents can be affected by climatic changes and influence biological and fisheries production in the region. Increase in temperature can enhance stratification and inhibit upwelling. Change in precipitation levels over the drainage basin of Rio de la Plata and Patos Lagoon can directly influence salt balance in coastal regions. Although studies have not yet looked at climate change implications on biological production in the region, there are initiatives being supported to look into this issue.

**25 April, 14:30 (W5-6037)**

## Hotspots in warming sub-arctic seas

George L. **Hunt**, Jr.

School Aquatic and Fishery Sciences, University of Washington, P.O. Box 355020, Seattle, WA, 98195-5020, USA
E-mail: geohunt2@u.washington.edu

To prioritize conservation efforts in terrestrial habitats, regions with extraordinary species richness have been designated as hotspots, as have areas with high species richness or endemism in low latitude marine systems. Also included in the hotspot concept are marine regions with high biomasses of top predators, that is, areas where trophic transfer to upper trophic levels is enhanced. At least two mechanisms promote these rich foraging opportunities. There may be regions of exceptionally high primary production that are sufficiently stable to promote the formation of a food web that reaches to the highest trophic levels. Alternatively, there may be interactions between physical processes and prey behavior that result in predictable aggregations of prey, much of which may have resulted from distant production. Within the sub-arctic seas, both mechanisms result in large aggregations of seabirds and possibly marine mammals. In these areas of aggregation, species diversity is not particularly high; in fact often one or two species dominate the foraging and one or perhaps two species of prey support the aggregation. It is not clear how these hotspots will respond to climate change. Those associated with ice edges are likely to retreat northward, and changes in the distribution or intensity of primary production may also affect hotspots dependent on local production. Likewise, changes in circulation patterns could impact those hotspots dependent on advection of prey. Since hotspots may account for considerable trophic transfer, the population consequences of changing hotspot distribution, abundance and prey densities is a research topic worthy of study.

# W6 Oral Presentations



**25 April, 13:00**

## Overview of some physical mechanisms that link physical forcing with zooplankton and fisheries response in the North Pacific

William T. **Peterson**

NOAA-Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR, 97365, USA
E-mail: bill.peterson@noaa.gov

Abstract N/A

**25 April, 13:20 (W6-6420)**

## Propagation of ecological anomalies from the western to eastern North Pacific in a global earth system model

Ryan R. **Rykaczewski**

University Corporation for Atmospheric Research, Geophysical Fluid Dynamics Laboratory, 201 Forrestal Rd., Princeton, NJ, 08540-6649, USA. E-mail: ryan.rykaczewski@noaa.gov

Synchrony in the variability among remote marine ecosystems has been observed at decadal scales, and ocean-atmosphere teleconnections have been investigated of as potential drivers of such variability. Here, I examine basin-wide variability in the depth of the nutricline across the mid-latitude North Pacific using a global, earth system model. In this model, interannual to decadal scale variability in the depth of wintertime convection in the western North Pacific stimulates anomalies in the vertical distribution of nitrate. These anomalies propagate from west to east with the North Pacific Current with a transit time on the scale of decades. As a result, anomalies in the deep-water nitrate concentration of the eastern North Pacific may be predicted several years in advance given knowledge of convection and vertical nitrate distribution in the western North Pacific. This teleconnection is one mechanism which may contribute to harmonization of decadal, ecological variability across the Pacific with a delayed response of the California Current relative to changes in the Kuroshio-Oyashio extension region. The further ecological significance of this relationship will be discussed.

**25 April, 13:40 (W6-6385)**

## The Pacific Decadal Oscillation and marine food webs in the northern California Current: Variations in source waters which feed the California Current may be the mechanism which links climate change with ecosystem response

William T. **Peterson**[1], Hongsheng Bi[2, 3], Cheryl A. Morgan[2] and Edmundo Casillas[1]

[1] NOAA-Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR, 97365, USA
E-mail: bill.peterson@noaa.gov
[2] Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, Oregon State University, Newport, OR, 97365, USA
[3] University of Maryland, Chesapeake Biological Laboratory, Solomons, MA, USA

Analysis of hydrographic and zooplankton data collected fortnightly in the coastal upwelling zone off Oregon for the past 14 years and historical observations from the 1970s ands 1980s have shown that variations in sea surface temperature, salinity, copepod biodiversity, species richness and community structure are correlated with the Pacific Decadal Oscillation. When the PDO is negative (as during the 1970s, 1999-2002 and 2008-2009), cold salty waters from the Gulf of Alaska feed the northern California Current (NCC) and transport large, lipid-rich copepods to the shelf waters of the NCC; when the PDO is positive (as in 2003-2007), warm fresher waters from offshore and south feed the NCC and transport small, oceanic lipid-poor copepods to the coast. Thus the basin-scale variations in winds that drive the PDO result in changes in transport that in turn control local food chain structure. These changes in food chain structure correlate with (and predict) salmon returns to the Columbia

River. We use altimeter data to show that changes in phase of the PDO are accompanied by changes in source waters which feed the NCC. We argue that to examine how the coastal upwelling ecosystem of the NCC might react to a climate change scenarios, we will need a better understanding of how basin-scale winds and variations in gyre circulation patterns impact source waters which feed the NCC. A combination of ROMS and GCMs should allow examination of future states of the PDO and of regional variations in source waters that feed the NCC.

**25 April, 14:00 (W6-6374)**

## Evidence of climate change in the northern California Current ecosystem and its impact on the distribution and community composition of zooplankton

Jay O. **Peterson**[1] and William T. Peterson[2]

[1] Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, Newport, OR, 97365, USA
E-mail: jay.peterson@oregonstate.edu
[2] NOAA-Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR, 97365, USA

Uncertainty exists in predictions of how climate change will impact aquatic ecosystems. For the California Current (USA), an eastern boundary current driven by upwelling, a warming climate is predicted to lead to increased water temperatures and stronger stratification, but also more intense periods of upwelling. Physical and biological data from the northern California Current (NCC) ecosystem have been collected at various frequencies since 1969, with the most intense and consistent sampling occurring from 1996 - present. This long-term dataset encompasses phase changes in the Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), and El Niño Southern Oscillation (ENSO) providing information on how the NCC ecosystem may respond to climate shifts leading to warmer or colder ocean conditions and changes in upwelling strength and duration. We will address the long-term trends in physical variables (temperature, stratification, timing and strength of upwelling) and the associated changes in the abundance and species composition of meso-zooplankton. Over the last 40 years we have found several fundamental changes in the NCC including an increase in the number of copepod species routinely found along the coast (0.11 species per year), an intensification of oxygen-depleted bottom waters on the shelf, and a deepening in the depth from which water upwells. Variability within these trends correlates to the phase of the PDO and provides an indication of how the ecosystem responds to both warmer and colder ocean conditions.

**25 April, 14:20 (W6-6047)**

## Potential effects of climate change on the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* off Newport, OR, USA

C. Tracy **Shaw**[1], Leah R. Feinberg[1] and William T. Peterson[2]

[1] Cooperative Institute for Marine Resources Studies, Oregon State University, 2030 SE Marine Science Drive, Newport, OR, 97365, USA
E-mail: tracy.shaw@oregonstate.edu
[2] Northwest Fisheries Science Center, NOAA Fisheries, 2030 SE Marine Science Drive, Newport, OR, 97365, USA

Climate change scenarios suggest that global warming will lead to stronger coastal upwelling and changes in the magnitude and duration of natural climate cycles such as the PDO. Our ongoing biweekly zooplankton sampling program (1996-present) encompasses variations in timing and intensity of upwelling and cool and warm phases of the PDO which allows us to investigate some potential effects of climate change on the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera*. *E. pacifica* spawning is strongly associated with the timing of the onset of upwelling but not with upwelling strength. Spawning peaks four months after the spring transition and juveniles appear two months later. In 2005 upwelling was delayed and krill spawning was similarly delayed. Survivorship of larvae produced that summer was considerably lower than during other years. *T. spinifera* spawn prior to and during upwelling and seem to be more strongly affected by water temperature. 2002 was an anomalously cold year and *T. spinifera*, usually a shelf species, were found far offshore. Their reproductive effort in 2002 was the highest seen during this study. *E. pacifica* were not strongly affected by temperature variations and were always present. *T. spinifera* were rare or absent during warmer ocean conditions. Changes in the timing of the spring transition are likely to affect *E. pacifica* spawning behavior. Consistently warmer ocean temperatures will likely lead to a decrease in *T. spinifera* abundance and spawning. Both scenarios will affect the availability of euphausiids as a food source for higher trophic level predators.

**25 April, 14:40 (W6-6372)**

## Impacts of wintertime upwelling and primary production on euphausiid phenology and the productivity of upper trophic levels in the northern California Current

Leah R. **Feinberg**[1] and William T. Peterson[2]

[1] Cooperative Institute for Marine Resources Studies, Oregon State University, 2030 SE Marine Science Dr., Newport, OR, 97365, USA. E-mail: leah.feinberg@oregonstate.edu
[2] Northwest Fisheries Science Center, NOAA Fisheries, 2030 SE Marine Science Dr., Newport, OR, 97365, USA

The northern California Current is highly productive and an important feeding ground for many fish, birds and mammals. We are examining the relationship between ocean conditions in the understudied wintertime period preceding the "official" upwelling season to evaluate the importance of this timeframe for setting up high levels of secondary productivity prior to and during the upwelling season. We are looking at egg production of the two dominant euphausiid species in relation to the daily upwelling index for 45°N, ocean color satellite data, and chlorophyll and zooplankton counts from our bi-weekly surveys off Newport, OR (44.65°N) during January – March from1997-2009.

We observed wintertime chlorophyll peaks only in 2002-2008, with the biggest peaks occurring in 2002, 2005 and 2007. The presence of these peaks is related to wintertime weather conditions and upwelling patterns. Exceptionally stormy winters did not lead to late winter phytoplankton blooms and in years when blooms did occur they typically followed a period of brief upwelling. *Thysanoessa spinifera* is the second most dominant euphausiid species in this region and is often cited as the preferred euphausiid prey for many fish and bird species. They are uniquely able to exploit these wintertime blooms and we have seen large wintertime peaks in their egg densities corresponding to these events. As we move into more uncertain climate scenarios, it is critical to recognize the year-round ocean conditions and resulting phenologies of these prey species as they may provide us a view into the mechanisms linking climate to fisheries.

**25 April, 15:00 (W6-6421)**

## Responses in growth rate of larval northern anchovy and Pacific sardine to anomalous upwelling in 2005 in the northern California Current

Motomitsu **Takahashi**[1], David M. Checkley, Jr.[2], Richard D. Brodeur[3] and William T. Peterson[3]

[1] Seikai National Fisheries Research Institute, Fisheries Research Agency, 1551-8 Taira-machi, Nagasaki, Nagasaki, 851-2213, Japan E-mail: takahamt@fra.affrc.go.jp
[2] Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Dr., La Jolla, CA, 92039-0218, USA
[3] NOAA-Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR, 97365, USA

We examined variability in growth rate during early life stages for northern anchovy and Pacific sardine in response to physical and biological environments in the northern California Current in 2005. Late larval and early juvenile anchovy and sardine were collected using a subsurface trawl net in August, September and October off Oregon and Washington. Hatch dates of northern anchovy ranged from late May to early September and those of Pacific sardine from mid May to early July based on the number of otolith daily increments. Widths of otolith daily increments during larval stage were standardized at their formation dates to zero mean and unit deviation as a proxy of seasonal variability in somatic growth rates. The standardized increment width (SIW) of northern anchovy was negative from June to mid August, changed to positive after late August and dropped in October, while no distinct trend was found in SIW of Pacific sardine. Biomass of neritic cold water copepod species increased sharply after July and began to decrease in October in the Newport Line Station NH-5. Changes in phytoplankton (chlorophyll) biomass were similar as those in the copepod biomass. Previous studies have reported that the onset of upwelling was delayed 2-3 months in 2005 and that upwelling intensified anomalously after mid July resulting in decreasing sea surface temperature. Our results suggest that intensification of upwelling after mid July led to the development of a bloom of phytoplankton and a surge in production of cold water copepod species and consequently an enhanced larval growth rate of northern anchovy in the coastal waters off Oregon and Washington in 2005.

**25 April, 15:50 (W6-6418)**

## Overview of the zooplankton from viewpoint of food for fish resources in the western North Pacific

Kazuaki **Tadokoro** and Yuji Okazaki

Tohoku National Fisheries Research Institute, 3-27-5 Shinhama-cho, Shiogama, Miyagi, 985-0001, Japan. E-mail: den@affrc.go.jp

The western North Pacific near to east coast of Japan is classified to Kuroshio and Oyashio Kuroshio-Oyashio transition waters. These waters have different oceanographic feature and are the important nursery area for commercially important fishes such as Japanese sardine and walleye pollack. The fish resources represented the significant interannual and interedecadal variation. The change in food condition in the environment is considered one of cause of the variation in fish resources. Therefore, the study of the food organisms is important to clarify the mechanism of the variations. The zooplankton represents long-term variation corresponding to the climate change such as the regime shifts and global warming. However, the effect of the change in zooplankton to fish resources is not well understood, because there are few studies based on viewpoint of food for fish resources. For example, variation of *Neocalanus* has been well studied in the Kuroshio-Oyashio transition waters because it is dominant zooplankton by biomass. However the larvae and juvenile of the Japanese sardine dose not utilize *Neocalanus* well. The sardine mainly utilizes small size copepod during their early life period. However the variation in small size copepod is not well studied. To clarify the effect to the change in zooplankton, study of the food habit of fish resources is need. We will present long-term variations in zooplankton in the western North Pacific, and how to investigate the zooplankton to understand the fish resource change.

**25 April, 16:10**

## Long-term variation in copepod community structure in the Kuroshio area, off southern Japan

Mikiko **Kuriyama**, Hiroya Sugisaki, Yuichi Hirota, Tadafumi Ichikawa, Hiroshi Itoh and Hiroshi Horikawa

Abstract N/A

**25 April, 16:30 (W6-6419)**

## Response of large grazing copepods to climate-oceanographic changes in the western subarctic Pacific Ocean

Toru **Kobari**[1], Kazuaki Tadokoro[2], Hiroya Sugisaki[3] and Hiroshi Ito[4]

1 Fisheries Biology and Oceanography, Faculty of Fisheries, Kagoshima University, 4-5-20 Shimoarata, Kagoshima, 890-0056, Japan
E-mail: kobari@fish.kagoshima-u.ac.jp
2 Mixed Water Region Fishery Oceanography Division, Tohoku National Fisheries Research Institute, Japan
3 Marine Productivity Division, National Research Institute of Fisheries Science, Japan
4 Suidosha Co. Ltd., Japan

To evaluate their response to climate-oceanographic conditions, interannual variations in seasonal abundance of Eucalanus bungii were investigated in zooplankton samples collected from the Oyashio Current system from 1960 to 2002. Large decadal changes were observed in seasonal timing and population age-structure. During the early 1970s and 1990s, E. bungii were abundant until mid-summer, but during the late 1970s and early 1980s, the season of maximum abundance was limited to spring and early summer. From the late 1970s to early 1980s, spring–summer abundance of newly recruited young copepodites (C1–C2) declined significantly, and an even more pronounced decline was observed for the abundance of the late copepodite stages (C3–C5). Monthly population structure showed that young of the year stopped development at C3 during the late 1970s to early 1980s, but molted into late copepodite stages in the other decades. Seasonal weakening of the Aleutian Low Pressure System estimated from North Pacific Index (NPI) was rapid during the late 1970s to early 1980s, and the NPI was positively correlated with phosphate concentrations at sea surface, spring–summer abundance of the young copepodites stages, and the extended duration of the season of high abundance. These results suggest that the decadal decline of copepod abundance originated at the early life stages, and was associated with a shift of atmospheric and oceanographic conditions. As possible biological mechanisms, we propose reduced egg production, lower survival for the portion of the annual cohort with late birth date, and overwintering of the survivors at younger stages.

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# Registrants

## (as of March 11)

## *Australia*

**Scott A. Condie**
CSIRO Marine and Atmospheric Research
GPO Box 1538
Hobart, Tasmania 7001
Australia
scott.condie@csiro.au

**Campbell Davies**
IMCAM Program
CSIRO Marine and Atmospheric Research
Castray Esplanade
Hobart, Tasmania 7000
Australia
campbell.davies@csiro.au

**Jennifer M. Donelson**
School of Marine and Tropical Biology
James Cook University
Townsville, QLD 4811
Australia
jennifer.donelson@jcu.edu.au

**Graham Edgar**
Institute of Marine and Antarctic Studies
University of Tasmania
GPO Box 252-49
Hobart, Tasmania 7001
Australia
g.edgar@utas.edu.au

**Stewart D. Frusher**
Tasmanian Aquaculture and Fisheries Institute
University of Tasmania
Marine Research Laboratories
Nubeena Crescent, Taroona
Hobart, Tasmania 7053
Australia
stewart.frusher@utas.edu.au

**Elizabeth A. Fulton**
CSIRO Marine and Atmospheric Research
P.O. Box 1538
Hobart, Tasmania 7001
Australia
beth.fulton@csiro.au

**Nicholas Graham**
ARC Centre of Excellence for Coral Reef Studies
James Cook University
Townsville, QLD 4811
Australia
nick.graham@jcu.edu.au

**Alistair J. Hobday**
CSIRO
Castray Esplanade
Hobart, Tasmania 7001
Australia
alistair.hobday@csiro.au

**Ingrid Holliday**
Department of Primary Industries Fisheries Victoria
22/1 Spring St.
Melbourne, Victoria 3001
Australia
Ingrid.L.Holliday@dpi.vic.gov.au

**So Kawaguchi**
Australian Antarctic Division
203 Channel Hwy
Kingston, Tasmania 7050
Australia
so.kawaguchi@aad.gov.au

**M. Aaron MacNeil**
Marine Biodiversity
Australian Institute of Marine Science
PMB 3 Townsville MC
Townsville, QLD 4810
Australia
a.macneil@aims.gov.au

**Philip L. Munday**
ARC Centre of Excellence for Coral Reef Studies, and School of Marine and Tropical Biology
James Cook University
Townsville, QLD 4814
Australia
philip.munday@jcu.edu.au

**Ana Norman-López**
Marine Climate Impacts and Adaptation
CSIRO
233 Middle St.
Cleveland, QLD 4163
Australia
ana.norman@csiro.au

**Melissa J. Nursey-Bray**
National Centre for Marine Conservation and Resource Sustainability
University of Tasmania
Australian Maritime College
Locked Bag 1370, Newnham
Launceston, Tasmania 7248
Australia
m.nursey-bray@amc.edu.au

**Gretta T. Pecl**
Tasmanian Aquaculture and Fisheries Institute
University of Tasmania
Private Bag 49
Hobart, Tasmania 7001
Australia
Gretta.Pecl@utas.edu.au

**Éva E. Plagányi**
CMAR, CSIRO
233 Middle St.
Brisbane, QLD 4163
Australia
Eva.Plaganyi-lloyd@csiro.au

**Elvira S. Poloczanska**
Climate Adaptation Flagship,
Marine and Atmospheric Research
CSIRO
P.O. Box 120
Cleveland, QLD 4163
Australia
elvira.poloczanska@csiro.au

**Ana Rubio-Zuazo**
Fisheries Research and
Development Corporation
29 Mullion Cl
Hornsby Heights, NSW 2077
Australia
anarubio.zuazo@gmail.com

**Andrew J. Tobin**
Fishing and Fisheries Research Centre
James Cook University
Townsville, QLD 4811
Australia
andrew.tobin@jcu.edu.au

**Renae C. Tobin**
Fishing and Fisheries Research Centre
School of Earth and Environmental
Sciences
James Cook University
Townsville, QLD 4811
Australia
renae.tobin@jcu.edu.au

## Belgium

**Philippe Moguedet**
DG Research (RTD), Unit E4 -
Agriculture, Forestry, Fisheries
and Aquaculture Research
Brussels, 1049
Belgium
philippe.moguedet@ec.europa.eu

## Brazil

**Maria A. Gasalla**
Fisheries Ecosystems Laboratory
Department of Biological
Oceanography
University of São Paulo Instituto
Oceanografico
Praça do Oceanografico, 191,
Cidade Universitaria
São Paulo, São Paulo 055080-900
Brazil
mgasalla@usp.br

**José H. Muelbert**
Instituto de Oceanografia
Universidade Federal do Rio Grande
Cx. Postal, 474
Rio Grande, RS 96201-900
Brazil
docjhm@furg.br

**Renato Azevedo Matias Silvano**
Department of Ecology
Universidade Federal do Rio
Grande do Sul
Av. Bento Goncalves, CP 15007
Porto Alegre, RS 91501-970
Brazil
renato.silvano@ufrgs.br

## Cameroon, Republic

**Nkemasong S. Acha**
Department of Fisheries
Action Centre for Rural Community
Development
P.O. Box 144, Buea
Buea, South West Region 237
Cameroon
acercd98@yahoo.com

**Tiku Felix**
Aquaculture and Fishery
Action Centre for Rural Community
Development
Buea University Junction
Bp 3230 Messa-Ya
Buea, South West Region 237
Cameroon
acercd72@yahoo.com

## Canada

**Robin Brown**
Fisheries and Oceans Canada
Institute of Ocean Sciences
P.O. Box 6000
Sidney, BC V8L 1J6
Canada
robin.brown@dfo-mpo.gc.ca

**Kenneth L. Denman**
Fisheries and Oceans Canada, and
Canadian Centre for Climate
Modelling and Analysis
c/o University of Victoria
P.O. Box 3065, STN CSC
Victoria, BC V8W 3V6
Canada
Ken.Denman@ec.gc.ca

**Nicholas K. Dulvy**
Department of Biological Sciences
Simon Fraser University
8888 University Dr.
Burnaby, BC V5A 1S6
Canada
nick_dulvy@sfu.ca

**Michael G. Foreman**
Fisheries and Oceans Canada
Institute of Ocean Sciences
P.O. Box 6000
Sidney, BC V8L 4B2
Canada
mike.foreman@dfo-mpo.gc.ca

**James R. Irvine**
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Rd.
Nanaimo, BC V9T 6N7
Canada
james.irvine@dfo-mpo.gc.ca

**Jacquelynne R. King (*Cancelled*)**
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Rd.
Nanaimo, BC V9T 6N7
Canada
Jackie.King@dfo-mpo.gc.ca

**Vicky Wing Yee Lam**
Fisheries Centre
The University of British Columbia
Fisheries Centre, Aquatic
Ecosystems Research Laboratory
Vancouver, BC V6T 1Z4
Canada
v.lam@fisheries.ubc.ca

**Lingbo Li (*Cancelled*)**
Fisheries Centre
The University of British Columbia
2202 Main Mall
Vancouver, BC V6T 1Z4
Canada
l.li@fisheries.ubc.ca

**Eduardo Martins**
Forest Sciences
The University of British Columbia
320-3755 W 6th Ave.
Vancouver, BC V6R 1T9
Canada
egmartins@gmail.com

**Skip McKinnell**
Deputy Executive Secretary
PICES Secretariat
P.O. Box 6000
Sidney, BC V8L 4B2
Canada
mckinnell@pices.int

**Tom Okey**
Ecosystem Sciences
West Coast Aquatic & UVic SES
#3 4310 10th Ave.
Port Alberni, BC V9Y 4X4
Canada
Thomas.Okey@gmail.com

**Ian Perry**
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Rd.
Nanaimo, BC V9T 6N7
Canada
Ian.Perry@dfo-mpo.gc.ca

**Randall M. Peterman**
School of Resource and
Environmental Management
Simon Fraser University
8888 University Dr.
Burnaby, BC V5A 1S6
Canada
peterman@sfu.ca

**Jake Rice**
Fisheries and Oceans Canada
Ecosystem Science Directorate
Station 12S014, 200 Kent St.
Ottawa, ON K1A 0E6
Canada
Jake.Rice@dfo-mpo.gc.ca

**Jacob F. Schweigert**
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Rd.
Nanaimo, BC V9T 6N7
Canada
Jake.Schweigert@dfo-mpo.gc.ca

**Ussif Rashid Sumaila**
Fisheries Centre
The University of British Columbia
2202 Main Mall
Vancouver, BC V6T 1Z4
Canada
r.sumaila@fisheries.ubc.ca

**Strahan Tucker**
Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Rd.
Nanaimo, BC V9T 6N7
Canada
strahan.tucker@dfo-mpo.gc.ca

**Shigehiko Urawa**
North Pacific Anadromous Fish
Commission
Suite 502, 889 West Pender St.
Vancouver, BC V6C 3B2
Canada
urawa@npafc.org

## *Chile*

**Claudio A. Castillo-Jordán**
Department of Oceanography
University of Concepción
Las Vegas 1326, Cabina 9
Universidad de Concepción
Concepción, 4070423
Chile
clacastillo@udec.cl

**Luis A. Cubillos**
Department of Oceanography
University of Concepción
Barrio Universitario s/n
Concepción, 4070423
Chile
lucubillos@udec.cl

**Francisco Plaza (*Cancelled*)**
Av. Altamirano 1480
Valparáiso, 2360007
Chile
francisco.plaza@ucv.cl

**Eleuterio Yanez**
Escuela de Ciencas del Mar
Pontificia Universidad Católica de
Valparáiso
Av. Altamirano 1480
Valparáiso, Casilla 1020
Chile
eyanez@ucv.cl

## *China, People's Republic*

**Jingfeng Fan (*Cancelled*)**
Department of Marine
Environmental Ecology
National Marine Environmental
Monitoring Center, SOA
42 Linghe St., Shahekou District
Dalian, Liaoning 116023
PR China
fanjingfeng@163.com

**Licheng Feng**
National Marine Environmental Forecasting Center, SOA
8 Dahuisi Rd., Haidian District
Beijing, 100081
PR China
fenglich@gmail.com

**Shan Gao**
National Marine Environmental Forecasting Center, SOA
S8 Dahuisi Rd., Haidian District
Beijing, 100081
PR China
gaoshan_shining@163.com

**Chunjiang Guan**
National Marine Environmental Monitoring Center, SOA
42 Linghe St., Shahekou District
Dalian, Liaoning 116023
PR China
fb4680@people.com.cn

**Chunli Liu (*Cancelled*)**
180 West Wenhua Rd.
Weihai, Shandong 264209
PR China
liuchunli@china.com.cn

**Guimei Liu**
National Marine Environmental Forecasting Center, SOA
8 Dahuisi Rd., Haidian District
Beijing, 100081
PR China
guimei.liu@umit.maine.edu

**Zhou Qiulin**
State Oceanic Administration
Third Institute of Oceanography
178 Daxue Rd.
Xiamen, Fujian 361005
PR China
zhou@public.xm.fj.cn

**Yang Sheng-yun**
182 Daxue Rd.
Xiamen, Fujian 361005
PR China
yangsy@xmu.edu.cn

**Hui Wang**
National Marine Environmental Forecasting Center, SOA
8 Dahuisi Rd., Haidian District
Beijing, 100081
PR China
wangh@nmefc.gov.cn

**Zhang Gui Wang**
Climate Change
National Research Center for Marine Environmental Forecasting
8 Dahuisi Rd., Haidian District
Beijing, 100081
PR China
zhangguiwang_4@yahoo.cn

**Hao Wei**
College of Marine Science and Engineering
Tianjin University of Science and Technology
29, 13th Ave., TEDA
Tianjin, 300457
PR China
weihao@ouc.edu.cn

**Qianguo Xing (*Cancelled*)**
Yantai Institute of Coastal Zone Research
Chinese Academy of Sciences
17 Chunhui Rd., Laishan
Yantai, Shangdong 264003
PR China
qgxing@yic.ac.cn

**Huaming Yu**
College of Physical and Environmental Oceanography
Ocean University of China
238 Songling Rd.
Qingdao, Shandong 266100
PR China
huamingyu@gmail.com

**Xuelei Zhang (*Cancelled*)**
Center for Marine Ecology Research
First Institute of Oceanography, SOA
6 Xian-Xia Ling Rd.
Hi-Tech Park, LaoShan District
Qingdao, Shandong 266061
PR China
zhangxl@fio.org.cn

**Qiulin Zhou**
Third Institute of Oceanography, SOA
178 Daxue Rd.
Xiamen, Fujian 361005
PR China
zhou@public.xm.fj.cn

## *China-Taipei*

**Feng-Chen Chang (*Cancelled*)**
Institute of Oceanography
National Taiwan University
1-Sec. 4, Roosevelt Rd.
Taipei, Taiwan 106
China-Taipei
fengchen@ofdc.org.tw

**Yi-Jay Chang**
1-Sec. 4, Roosevelt Rd.
Taipei, 106
China-Taipei
chisboy@gmail.com

**Yu-Kai Chen**
Marine Fisheries Division
Fisheries Research Institute
199 Hou-Ih Rd.
Keelung, 20246
China-Taipei
ykchen@mail.tfrin.gov.tw

**Hung-Yen Hsieh**
Coastal and Offshore Resources Research Center
Fisheries Research Institute
1-1, Yugang N. 1st Rd.
Kaohsiung, 80672
China-Taipei
hyhsieh@mail.tfrin.gov.tw

**Chih-Chieh Hsu**
Earth Dynamic System Research Center, NCKU
1 University Rd.
Tainan, 701
China-Taipei
d94b45003@ntu.edu.tw

**Kuo-Wei Lan**
Environmental Biology Fisheries Science
National Taiwan Ocean University
2 Pei-Ning Rd.
Keelung, 20224
China-Taipei
aaman72422@msn.com

**Ming-An Lee**
Department of Environmental Biology and Fisheries Science
National Taiwan Ocean University
2 Pei-Ning Rd.
Keelung, 20224
China-Taipei
malee@mail.ntou.edu.tw

**Wen-Tseng Lo**
Institute of Marine Biotechnology and Resources
National Sun Yat-Sen University
70 Lien-Hai Rd.
Kaohsiung, Taiwan 80424
China-Taipei
lowen@mail.nsysu.edu.tw

**Hsueh-Jung Lu**
Environmental Biology and Fishery Science
National Taiwan Ocean University
2 Pei-Ning Rd.
Keelung, 20224
China-Taipei
hjlu@ntou.edu.tw

**Nan-Jay Su**
Institute of Oceanography
National Taiwan University
1-Sec. 4, Roosevelt Rd., Rm. 413
Taipei, 10617
China-Taipei
nanjay@ntu.edu.tw

**Chi-Lu Sun**
Institute of Oceanography
National Taiwan University
1-Sec. 4, Roosevelt Rd.
Taipei, 10617
China-Taipei
chilu@ntu.edu.tw

**Chen-Te Tseng**
Fisheries Research Institute
199 Hou-Ih Rd.
Keelung, 202
China-Taipei
cttseng@mail.tfrin.gov.tw

**Chia-Hui Wang**
Earth Dynamic System Research Center
National Cheng Kung University
1 University Rd.
Tainan, 704
China-Taipei
chwang@mail.ncku.edu.tw

**Su-Zan Yeh**
Institute of Oceanography
National Taiwan University
1-Sec. 4, Roosevelt Rd.
Taipei, 10617
China-Taipei
suzanyeh@ntu.edu.tw

## Denmark

**Francois Bastardie**
Technical University of Denmark
DTU-Aqua
Charlottenlund Castle
Charlottenlund, DK-2920
Denmark
fba@aqua.dtu.dk

**Keith Brander (*Cancelled*)**
Technical University of Denmark
National Institute of Aquatic Resources
Charlottenlund Slot, Jægersborg Allé 1
Charlottenlund, DK-2920
Denmark
kbr@aqua.dtu.dk

**Adolf K. Kellermann**
Science Programme
International Council for the Exploration of the Sea (ICES)
H.C. Andersens Blvd. 44-46
Copenhagen V, DK-1553
Denmark
adi@ices.dk

**Martin O. Lindegren**
National Institute of Aquatic Resources
Technical University of Denmark
Charlottenlund Castle
Charlottenlund, DK-2920
Denmark
mli@aqua.dtu.dk

## Egypt

**Ouwashola Bayo Popoola**
Department of Fisheries
International British Institute
13 Qumbis St.
Heliopolis, Cairo 11451
Egypt
ibinstitutecairo@yahoo.com

## Estonia

**Ulo Suursaar**
Estonian Marine Institute,
University of Tartu
Maealuse 14
Tallinn, 12618
Estonia
ulo.suursaar@ut.ee

## France

**Arnaud Bertrand (*Cancelled*)**
IRD
CRH, Ave. Jean Monnet
Sète, 34203
France
Arnaud.Bertrand@ird.fr

**Philippe M. Cury**
IRD
CRH, Ave. Jean Monnet, B.P. 171
Sète, 34203
France
philippe.cury@ird.fr

**Olga Hernandez**
CLS
8-10, rue Hermès, Parc Technologique du Canal
Ramonville Saint-Agne, 31520
France
ohernandez@cls.fr

**Pierre Petitgas**
Ecology and Models for Fisheries Science
IFREMER
Rue de l'Ile d'Yeu, B.P. 21105
Nantes, 44311
France
pierre.petitgas@ifremer.fr

**Cyril Piou**
UMR ECOBIOP
INRA - Pôle d'Hydrobiologie de Saint Pée sur Nivelle, Q
Saint Pee sur Nivelle, 64310
France
cyril.piou@yahoo.fr

**Gabriel Reygondeau**
Institut de Recherche pour le Développement
CRH- Ave. Jean Monnet, B.P. 171
Sète, 34203
France
gabriel.reygondeau@hotmail.fr

## Germany

**Juergen Alheit**
Biological Oceanography
Leibniz Institute for Baltic Sea Research
Seestr. 15, Warnemuende, 18119
Germany
juergen.alheit@io-warnemuende.de

**Milena Arias-Schreiber**
Social-Ecological Systems Analysis
Leibniz Center for Tropical Marine Ecology
Fahrenheitstrasse 6
Bremen, Bremen D-28359
Germany
milena@uni-bremen.de

**Wolfgang Fennel**
IOW
Seestr. 15, Rostock, 18119
Germany
wolfgang.fennel@io-warnemuende.de

**Marc Hufnagl**
Institute of Hydrobiology and Fisheries Science
University of Hamburg
Olbersweg 24
Hamburg 22767
Germany
marc.hufnagl@uni-hamburg.de

**Ruben J. Lara**
Wetland Biogeochemistry
Leibniz Centre for Tropical Marine Ecology
Fahrenheitstrasse 6
Bremen, D-28359
Germany
ruben.lara@zmt-bremen.de

**Juan Carlos Molinero**
Marine Ecology/Experimental Ecology
IFM-GEOMAR
Düsternbrooker Weg 20
Kiel, 24105
Germany
jmolinero@ifm-geomar.de

**Eva Papaioannou**
Department of Geography
Christian Albrechts University of Kiel
Ludewig-Meyn Str. 14
Kiel, 24098
Germany
papaioannou@geographie.uni-kiel.de

**Myron A. Peck**
Center for Marine and Climate Research
University of Hamburg
Olbersweg 24
Hamburg, 22767
Germany
myron.peck@uni-hamburg.de

**Hans O. Pörtner**
Integrative Ecophysiology
Alfred-Wegener-Institute
Am Handelshafen 12
Bremerhaven, 27570
Germany
hans.poertner@awi.de

**Jörn O. Schmidt**
Sustainable Fishery - Economics Dept.
University of Kiel
Wilhelm-Seelig-Platz 1
Kiel, 24118
Germany
jschmidt@economics.uni-kiel.de

**Rüdiger Voss**
Sustainable Fishery - Economics Dept.
University of Kiel
Wilhelm-Seelig Platz 1
Kiel, 24118
Germany
voss@economics.uni-kiel.de

## Ghana

**Lailah G. Lartey-Antwi**
Marine Science Research
Smart Youth Volunteers Foundation
P.O. Box OS 2337, OSU
Accra, 00233
Ghana
lailah.lailah@gmail.com

## Greece

**Christos D. Maravelias**
Hellenic Centre for Marine Research
46.7 km Athens-Sounio Ave.
Athens, Anavyssos 19013
Greece
cmaravel@ath.hcmr.gr

**Dimitrios Politikos**
Hellenic Centre for Marine Research
Milou 9
Athens, 15127
Greece
dimpolit@ath.hcmr.gr

**George Triantafyllou**
Institute of Oceanography
Hellenic Centre for Marine Research
46.7 km Athens-Sounio Ane.
Mavro Lithari
P.O. Box 712
Anavissos, Attica 19013
Greece
gt@ath.hcmr.gr

## India

**Sunil D. Ahirrao**
Department of Fisheries
Shri Shivaji College Parbhani
Basmath Rd.
Parbhani, Maharashtra 91 431401
India
ahirrao.sunil@gmail.com

**Sekharapilla Premjith**
Department of Zoology
St. Judes College, M.S. University
Lekshmivilas, TC 10/1148
Vattiyoorkavu, Trivandrum
Thiruvananthapuram
Kerala 695013
India
drpremjith@rediffmail.com

**Sajeev Raveendran**
Department of Physical Oceanography
Cochin University of Science and Technology
School of Marine Sciences
Foreshore Rd., Fine Arts Ave.
Cochin, Kerala 91-682 016
India
rsajeev@yahoo.com

**Rosamma Stephen**
Biological Oceanography
National Institute of Oceanography
Ajantha, 43/1459
Kaloor- Kadavanthra Road,
Kochi, Kerala 682017
India
rosamma.stephen@gmail.com

## Indonesia

**Suzy Anna**
Faculty of Fisheries and Marine Science
Padjadjaran University
Jl. Raya Jatinangor Km 21
Bandung, West Java 40600
Indonesia
suzyanna18@gmail.com

**Riyanto Basuki**
Conservation and Marine National Park
Ministry of Marine Affairs and Fisheries
Merdeka Timur No.16, 10th Floor
Mina Bahari III Bldg.
Jakarta, DKI 10110
Indonesia
riyanbas@yahoo.com

**Akhmad Fauzi**
Department of Resource and Environmental Economics
Bogor Agricultural University (IPB)
Jl. Kamper Wing 5 Level 5
Kampus IPB Darmaga
Bogor, West Java 16680
Indonesia
fauziakhmad@gmail.com

**Aida Sartimbul**
Fisheries and Marine Science Resources Utility, Faculty of Fisheries and Marine Sciences
University of Brawijaya
Jalan Veteran
Malang, East Java 65145
Indonesia
aida@brawijaya.ac.id

**Anthony Darmawan Mulya Siahaan**
Legal Bureau
Ministry of Marine Affairs and Fisheries of the Rpublic of Indonesia
Jalan Medan Merdeka Timur
Nomor. 16
Jakarta, DKI Jakarta 10110
Indonesia
anthony-dms@hotmail.com

## Ireland

**Kathryn M. Hughes**
Marine Environment
Martin Ryan Institute
National University of Ireland, Galway
203 MRI Annexe
County Galway
Ireland
k.hughes4@nuigalway.ie

## Italy

**Tarub Bahri**
FIRF-F615, FAO
Via delle Terme di Caracalla
Rome, 00153
Italy
Tarub.Bahri@fao.org

**Kevern Cochrane**
FAO FIRD
Via delle Terme di Caracalla
Rome, 00100
Italy
Kevern.Cochrane@fao.org

**Cassandra De Young**
Department of Fisheries and Aquaculture
UN FAO
Rm. F-421
Viale delle Terme di Caracalla
Rome, 00153
Italy
cassandra.deyoung@fao.org

**Chiara Papetti**
Department of Biology
University of Padova
Via U. Bassi 58/b
Padova, Padova 35121
Italy
chiara.papetti@unipd.it

**Marti Pujolar**
Department of Biology
University of Padova
Via G. Colombo 3
Padova, 35131
Italy
martipujolar@gmail.com

## Japan

**Hasan M. Abdullah**
River Basin Research Center
Gifu University
1-1 Yanagido
Gifu, 501-1112
Japan
hasan@green.gifu-u.ac.jp

**Daisuke Ambe**
National Research Institute of Fisheries Science, FRA
2-12-4 Fukuura, Kanazawa
Yokohama, Kanagawa 236-8648
Japan
ambe@affrc.go.jp

**Hernando Pactao Bacosa**
Graduate School of Environmental Studies
Tohoku University
Aoba 6-6-20 Aramaki, Aoba-ku,
Sendai, Miyagi 980-8579
Japan
bacosa@er.kankyo.tohoku.ac.jp

**Awantha Dissanayake**
Institute for East China Sea Research
Nagasaki University
1551-7 Taira-machi
Nagasaki, Nagasaki 851-2213
Japan
awantha@nagasaki-u.ac.jp

**Rizalita R. Edpalina**
Operating Unit Ishikawa Kanazawa (OUIK)
United Nations University-Institute of Advanced Studies
Ishikawa-ken, Hirosaka-chosha,
2/F 2-1-1, Hirosaka, Kan
Kanazawa, Ishikawa 920-0962
Japan
epinephilus@yahoo.com

**Yoshinari Endo**
Graduate School of Agricultural Science
Tohoku University
1-1 Tsutsumi-dori
Amamiya-machi, Aoba-ku
Sendai, Miyagi 981-8555
Japan
yendo@bios.tohoku.ac.jp

**Masaaki Fukuwaka**
Hokkaido National Fisheries Research Institute, FRA
116 Katsurakoi
Kushiro, Hokkaido 085-0802
Japan
fukuwaka@fra.affrc.go.jp

**Ian Gleadall**
Faculty of Agriculture
Tohoku University
1-1 Amamiya, Aoba-ku
Sendai, 981-8555
Japan
octopus@bios.tohoku.ac.jp

**Tomoaki Goto**
Iwate Fisheries Technology Center
3-75-3 Heita
Kamaishi, Iwate 026-0001
Japan
t-gotou@pref.iwate.jp

**Taketo Hashioka**
Environmental Biogeochemical Cycle Research Program
Research Institute for Global Change, JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama, Kanagawa 236-0001
Japan
hashioka@jamstec.go.jp

**Kazuhiko Hiramatsu**
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, 164-8639
Japan
khiramatsu@ori.u-tokyo.ac.jp

**Takafumi Hirata**
Graduate School of Environmental Science
Hokkaido University
N10W5 Kita-ku
Sapporo, Hokkaido 060-0810
Japan
tahi@ees.hokudai.ac.jp

**Felipe Hurtado Ferro**
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, 164-8639
Japan
felipehurtado@nenv.k.u-tokyo.ac.jp

**Yukimasa Ishida**
Tohoku National Fisheries Research Institute, FRA
3-27-5 Shinhama-cho
Shiogama, Miyagi 985-0001
Japan
ishiday@fra.affrc.go.jp

**Atsushi Ishimatsu**
Institute for East China Sea Research
Nagasaki University
1551-7 Taira-machi
Nagasaki, 851-2213
Japan
a-ishima@nagasaki-u.ac.jp

**Gakushi Ishimura**
Center for Sustainablity Science
Hokkaido University
Kita 9 Nishi 8 Kita-ku
Sapporo, Hokkaido 0600809
Japan
gakugaku@sgp.hokudai.ac.jp

**Shin-ichi Ito**
Tohoku National Fisheries Research Institute, FRA
3-27-5 Shinhama-cho
Shiogama, Miyagi 985-0001
Japan
goito@affrc.go.jp

**Sachihiko Itoh**
Fisheries Environmental Oceanography Division
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, 164-8639
Japan
itohsach@ori.u-tokyo.ac.jp

**Yasuo Itoh**
Central Laboratory
Marine Ecology Research Institute
300 Iwawada
Onjuku-machi, Chiba 299-5105
Japan
itoh@kaiseiken.or.jp

**Masahide Kaeriyama**
Graduate School of Fishereis Sciences
Hokkaido University
3-1-1 Minato-cho
Hakodate, Hokkaido 041-8611
Japan
salmon@fish.hokudai.ac.jp

**Manami Kanno**
Field Science Center
Tohoku University
Mukai 15, Konorihama, Onagawa
Oshika, Miyagi 9862242
Japan
manami-k@bios.tohoku.ac.jp

**Yuu Katsukawa**
Ocean Research Institute
1-15-1 Minamidai
Nakano-ku, 164-8639
Japan
y.katukawa@gmail.com

**Michio Kawamiya**
Japan Agency for Marine-Earth Science and Technology
Frontier Research Center for Global Change, JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama, 236-0001
Japan
kawamiya@jamstec.go.jp

**Tsuyoshi Kawasaki**
Earth Environmental Science
1-10-6 Kugenuma-Fujigaya
Fujisawa, Kanagawa 251-0031
Japan
aceg-1937-xz@cfnet.ne.jp

**Kuroda Kazunori**
3-6-1-1009 Akitsu
Narashino
Chiba Prefecture 275-0025
Japan
kuroda121625@ivy.ocn.ne.jp

**Hideaki Kidokoro**
Japan Sea National Fisheries Research Institute, FRA
1-5939-22 Suido-cho
Niigata, Niigata 951-8121
Japan
kidokoro@fra.affrc.go.jp

**Michio J. Kishi**
Graduate School of Environmental Science
Hokkaido University
N10W5 Kita-ku
Sapporo, Hokkaido 060-0810
Japan
mjkishi@nifty.com

**Jun Kita**
Demonstration Laboratory
Marine Ecology Research Institute
4-7-17 Arahama
Kashiwazaki, Niigata 945-0017
Japan
kita@kaiseiken.or.jp

**Toru Kobari**
Faculty of Fisheries
Kagoshima University
4-50-20 Shimoarata
Kagoshima, Kagoshima 890-0056
Japan
kobari@fish.kagoshima-u.ac.jp

**Kosei Komatsu**
Graduate School of Frontier Sciences
The University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, 164-8639
Japan
kosei@ori.u-tokyo.ac.jp

**Teruhisa Komatsu**
Ocean Research Institute
The University of Tokyo
1-15-1, Minamidai
Nakanoku, Tokyo 164-8639
Japan
cymodocea@gmail.com

**Teruhisa Komatsu**
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai
Nakano-ku, Tokyo 164-8639
Japan
komatsu@ori.u-tokyo.ac.jp

**Haruko Kurihara**
Transdisciplinary Research Organization for Subtropical Island Studies
University of the Ryukyus
1 Senbaru, Nishihara
Okinawa, 903-0213
Japan
harukoku@e-mail.jp

**Yutaka Kurita**
Tohoku National Fisheries Research Institute, FRA
3-27-5 Shinhama-cho
Shiogama, Miyagi 985-0001
Japan
kurita@affrc.go.jp

**Mikiko Kuriyama**
National Research Institue of Fisheries Science, FRA
2-12-4 Fukuura, Kanazawa-ku
Yokohama, Kanagawa 236-8648
Japan
mikiko@affrc.go.jp

**Hiroshi Kuroda**
Marine Environmental Data Integrated Analysis Center
National Research Institute of Fisheries Science, FRA
2-12-4 Fukuura, Kanazawa-ku
Yokohama, Kanagawa 236-8648
Japan
kurocan@affrc.go.jp

**Masao Kurogi**
Research Institute for Global Change
Japan Agency for Marine-Earth Science and Technology, JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama, 236-0001
Japan
m_kurogi@jamstec.go.jp

**Kedarnath Mahapatra**
Earth Weather Inc. / Institute of Oceanic Research and Development
Tokai University
3-20-1 Orido, Shimizu-ku
Shizuoka, Shizuoka Prefecture
424-8610
Japan
kedar@scc.u-tokai.ac.jp

**Masao Miura**
Marine Environment
Marine Ecology Research Institute
300 Iwawada
Onjuku-machi, Chiba 299-5105
Japan
m-miura@kaiseiken.or.jp

**Yasuyuki Miyakoshi**
Hokkaido Fish Hatchery
373 Kitakashiwagi 3
Eniwa, Hokkaido 061-1433
Japan
miyakoshiy@fishexp.pref.hokkaido.jp

**Yasumasa Miyazawa**
Research Institute for Global Change
Japan Agency for Marine-Earth Science and Technology, JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama, Kanagawa 236-0001
Japan
miyazawa@jamstec.go.jp

**Masako Nakamura**
Sesoko Station
Tropical Biosphere Research Center
University of the Ryukyus
3422 Sesoko
Motobu, 905-0227
Japan
m_coral29@yahoo.co.jp

**Gregory N Nishihara**
Institute for East China Sea Research
Nagasaki University
1551-7 Taira-machi
Nagasaki, Nagasaki 851-2213
Japan
greg@nagasaki-u.ac.jp

**Haruka Nishikawa**
Living Marine Resources
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, 164-8639
Japan
harukan@ori.u-tokyo.ac.jp

**Yukihiro Nojiri**
Center for Global Environmental Research
National Institute for Environmental Studies (NIES)
16-2 Onogawa
Tsukuba, Ibaraki 305-8506
Japan
nojiri@nies.go.jp

**Masami Nonaka**
Climate Variation Predictability and Applicability Research Program
Research Institute for Global Change, JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama, Kanagawa 236-0001
Japan
nona@jamstec.go.jp

**Masakatsu Ohyama**
NOWPAP RCU
UNEP
5-5 Ushijima Shin-machi
Toyama 930-0856
Japan
masakatsu.ohyama@nowpap.org

**Yuji Okazaki**
Mixed Water Region Fisheries Oceanography Division
Tohoku National Fisheries Research Institute, FRA
3-27-5 Shinhama-cho
Shiogama, Miyagi 985-0001
Japan
okazakiy@affrc.go.jp

**Takeshi Okunishi**
National Research Institute of Fisheries Science, FRA
2-12-4 Fukuura, Kanazawa-ku
Yokohama, Kanagawa 236-8648
Japan
okunishi@affrc.go.jp

**Tsuneo Ono**
Subarctic Fisheries Oceanography Division
Hokkaido National Fisheries Research Institute, FRA
116 Katsurakoi
Kushiro, Hokkaido 085-0802
Japan
tono@fra.affrc.go.jp

**Pedcris M. Orencio**
Division of Environmental Science Development
Graduate School of Environmental Science
N10W5 Kita-ku
Sapporo, Hokkaido 060-0810
Japan
pedorencio@ees.hokudai.ac.jp

**I Nyoman Radiarta**
Faculty of Fisheries Sciences
Hokkaido University
3-1-1 Minato-cho
Hakodate, Hokkaido 041-8611
Japan
radiarta@salmon.fish.hokudai.ac.jp

**Hiroaki Saito**
Biological Oceanography Section
Tohoku National Fisheries Research Institute, FRA
3-27-5 Shinhama-cho
Shiogama, Miyagi 985-0001
Japan
hsaito@affrc.go.jp

**Sei-ichi Saitoh**
Graduate School of Fisheries Sciences
Hokkaido University
3-1-1 Minato-cho
Hakodate, Hokkaido 041-8611
Japan
ssaitoh@salmon.fish.hokudai.ac.jp

**Takashi T. Sakamoto**
Global Warming Research Project for IPCC AR5/Research Institute for Global Change, JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama, Kanagawa 236-0001
Japan
teng@jamstec.go.jp

**Yasunori Sakurai**
Graduate School of Fisheries Sciences
Hokkaido University
3-1-1 Minato-cho
Hakodate, Hokkaido 041-8611
Japan
sakurai@fish.hokudai.ac.jp

**Kazumi Sakuramoto**
Department of Ocean Sciences
Tokyo University of Marine Science and Technology
4-5-7 Konan
Minato-ku, Tokyo 108-8477
Japan
sakurak@kaiyodai.ac.jp

**Hyunju Seo**
Marine Bioresource and Environmental Science Division
Hokkaido University
3-1-1 Minato-cho
Hakodate, Hokkaido 041-8611
Japan
uagiri@hanmail.net

**Ikutaro Shimizu**
Fisheries Economy Division
National Research Institute of Fisheries Science, FRA
2-12-4 Fukuura, Kanazawa-ku
Yokohama, Kanagawa 236-8648
Japan
ikutaro@affrc.go.jp

**Jun Shoji**
Takehara Fisheries Research Lab.
Hiroshima University
5-8-1 Minato-machi
Takehara, Hiroshima 725-0024
Japan
jshoji@hiroshima-u.ac.jp

**Koji Sugie**
Central Research Institute of Electric Power Industry
1646 Abiko
Abiko, Chiba 270-1194
Japan
sugie@criepi.denken.or.jp

**Takashige Sugimoto**
School of Marine Science and Technology
Tokai University
3-20-1 Orido, Shimizu-ku
Shizuoka, Shizuoka Prefecture
424-8610
Japan
sugimoto@scc.u-tokai.ac.jp

**Hiroya Sugisaki**
National Research Institute of Fisheries Science, FRA
2-12-4 Fukuura, Kanazawa-ku
Yokohama, Kanagawa 236-8648
Japan
sugisaki@affrc.go.jp

**Mika Suhara**
Biology of Fisheries Resources
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai
Nakano-ku, Tokyo 164-8639
Japan
suhara@ori.u-tokyo.ac.jp

**Hiroshi Sumata**
Graduate School of Environmental Science
Hokkaido University
N10W5 Kita-ku
Sapporo, Hokkaido 060-0810
Japan
su@ees.hokudai.ac.jp

**Ryota Suwa**
Seto Marine Biological Laboratory
Field Science Education and Research Center
459 Nishimuro, Shirahama,
Wakayama 649-2211
Japan
ryota@zenno.jp

**Naoki Suzuki**
Ocean Sciences
Tokyo University of Marine Science and Technology
4-5-7 Konan, Minato-ku
Tokyo, 108-8477
Japan
naoki@kaiyodai.ac.jp

**Yoshimi Suzuki**
Environmentral Science
Shizuoka University
836 Oya Surugaku
Shizuoka, Shizuoka Prefecture
422-8529
Japan
foodwebyoshi@aol.com

**Mega L. Syamsuddin**
Graduate School of Fisheries Sciences
Hokkaido University
3-1-1 Minato-cho
Hakodate, Hokkaido 041-8611
Japan
mega@salmon.fish.hokudai.ac.jp

**Kazuaki Tadokoro**
Stock Productivity Section
Tohoku National Fisheries Research Institute, FRA
3-27-5 Shinhama-cho
Shiogama, Miyagi 985-0001
Japan
den@affrc.go.jp

**Motomitsu Takahashi**
East China Sea Fisheries Research Division
Seikai National Fisheries Research Institute, FRA
1551-8 Taira-machi
Nagasaki, Nagasaki 851-2213
Japan
takahamt@fra.affrc.go.jp

**Hideki Takami**
Tohoku National Fisheries Research Institute, FRA
3-27-5 Shinhama-cho
Shiogama, Miyagi 985-0001
Japan
htakami@affrc.go.jp

**Akiko Takano**
4-5-7 Konan, Minato-ku
Tokyo, 108-8477
Japan
sheepchild@gmail.com

**Akinori Takasuka**
Stock Assessment Division
National Research Institute of Fisheries Science, FRA
2-12-4 Fukuura, Kanazawa-ku
Yokohama, Kanagawa 236-8648
Japan
takasuka@affrc.go.jp

**Hiroaki Tatebe**
Research Institute for Global Change, JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama, Kanagawa 236-0001
Japan
tatebe@jamstec.go.jp

**Takeshi Terui**
Graduate School of Environmental Science
Hokkaido University
N10W5 Kita-ku
Sapporo, Hokkaido 060-0810
Japan
tk4terui@ees.hokudai.ac.jp

**Yongjun Tian**
Japan Sea Fisheries Resources Division
Japan Sea National Fisheries Research Institute, FRA
1-5939-22 Suido-cho, Chuo-ku
Niigata, 951-8121
Japan
yjtian@fra.affrc.go.jp

**Minoru Tomiyama**
1-3-2 Sannomaru
Nagoya, Aichi 470-2105
Japan
mtomi331@ybb.ne.jp

**Shinji Uehara**
Tohoku National Fisheries Research Institute, FRA
3-27-5 Shinhama-cho
Shiogama, Miyagi 985-0001
Japan
ueshin@affrc.go.jp

**Kazuhito Watanabe**
Miyagi Prefecture Fisheries Technology Institute
97-6, Sodenohama, Watanoha
Ishinomaki, Miyagi 986-2135
Japan
watanabe-ka825@pref.miyagi.jp

**Tatsuro Watanabe**
Physical Oceanography Section
Japan Sea National Fisheries Research Institute, FRA
1-5939-22 Suido-cho
Niigata, 951-8121
Japan
tatsuro@fra.affrc.go.jp

**Yoshiro Watanabe**
Living Marine Resources
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, 164-8639
Japan
ywatanab@ori.u-tokyo.ac.jp

**Nam-Il Won**
Biology of Fisheries Resources
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, 164-8639
Japan
niwon@ori.u-tokyo.ac.jp

**Hidemasa Yamamoto**
CEARAC (Special Monitoring and Coastal Environmental Assessment Regional Activity Centre)
NOWPAP (Northwest Pacific Action Plan)
5-5 Ushijima Shin-machi
Toyama 930-0856
Japan
h-yamamoto@npec.or.jp

**Yasuhiro Yamanaka**
Faculty of Environmental Earth Science
Hokkaido University
N10W5 Kita-ku
Sapporo, Hokkaido 060-0810
Japan
galapen@ees.hokudai.ac.jp

**Yoh Yamashita**
Field Science Education and Research Center
Kyoto University
Fisheries Research Station, Nagahama
Maizuru, Kyoto 625-0086
Japan
yoh@kais.kyoto-u.ac.jp

**Yumiko Yara**
N10W5 Kita-ku
Sapporo, 060-0810
Japan
yara@ees.hokudai.ac.jp

**Ichiro Yasuda**
Ocean Research Institute
The University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, 164-8639
Japan
ichiro@ori.u-tokyo.ac.jp

**Akihiko Yatsu**
Seikai National Fisheries Research Institute, FRA
1551-8 Taira-machi
Nagasaki, 851-2213
Japan
yatsua@fra.affrc.go.jp

**Naoki Yoshie**
Center for Marine Environmental Studies
Ehime University
2-5 Bunkyo-cho
Matsuyama, 790-8577
Japan
nyoshie@sci.ehime-u.ac.jp

**Hiroshi Yoshinari**
Physical Oceanography Section
Subarctic Fisheries Oceanography Division
Hokkaido National Fisheries Research Institute, FRA
116 Katsurakoi
Kushiro, Hokkaido 085-0802
Japan
hyy@affrc.go.jp

## ***Korea, Republic***

**Dong-Suck Chang**
The Natural Sciences
The National Academy of Sciences R Korea
375-13 Mang-ri, Wonsam-myeon
Yongin, Gyeonggi-do 449-871
R Korea
dschang40@hanmail.net

**Ji Hwan Sung**
Department of Marine Biology
Pukyong National University
51 Yonghoro, Nam-gu
Busan, 608-737
R Korea
nise9@hanmail.net

**Bonggil Hyun**
Department of Southern Coastal Environmental Research
Korea Ocean R&D Institute (KORDI)
391 Jangmok-ri Jangmok-myon
Geoje, Kyungsangnam 656-830
R Korea
bghyun@kordi.re.kr

**Chan Joo Jang**
Climate Change and Coastal Disater Research Department
Korea Ocean R&D Institute (KORDI)
1270 Sa-dong
Ansan, Gyeonggi-do 426-170
R Korea
cjjang@kordi.re.kr

**Moon Kyung Jeong**
Department of Marine Biology
Pukyong National University
51 Yonghoro, Nam-gu
Busan, 806-737
R Korea
vere117@hotmail.com

**Sukgeun Jung**
Fisheries Resources Research Division
National Fisheries R&D Institute (NFRDI)
408-1 Shirang-ri, Kijang-up, Kijang-gun
Busan, 619-705
R Korea
sukgeun.jung@gmail.com

**Sukyung Kang**
Fisheries Resources Research Division
National Fisheries R&D Institute (NFRDI)
151-1 Haean-ro, Gijang-up, Gijang-gun
Busan, 619-705
R Korea
kangsk@nfrdi.go.kr

**Bo Kwang Kim**
Department of Marine Biology
Pukyong National University
591-1 Daeyeon 3-dong, Nam-gu
Busan, 608-737
R Korea
coke0727@naver.com

**Eunhye Kim**
Environmental Marine Sciences
Hanyang University
1271 Sa-3-dong Sangrok-gu
Ansan, Gyeonggi-do 426-791
R Korea
ehkim@hanyang.ac.kr

**Jin Koo Kim**
Department of Marine Biology
Pukyong National University
599-1 Daeyeon 3-dong, Nam-gu
Busan, 608-737
R Korea
taengko@hanmail.net

**Jung Jin Kim**
Department of Marine Biology
Pukyong National University
51 Yonghoro, Nam-gu
Busan, 608737
R Korea
theocean81@hotmail.com

**Suam Kim**
Department of Marine Biology
Pukyong National University
599-1 Daeyeon 3-dong, Nam-gu
Busan, 608-737
R Korea
suamkim@pknu.ac.kr

**Jae-Bong Lee**
Fisheries Resources Research Division
National Fisheries R&D Institute (NFRDI)
408-1 Shirang-ri, Kijang-up, Kijang-gun
Busan, 619-705
R Korea
leejb@nfrdi.go.kr

**Jong Hee Lee**
Marine Production Management
Pukyong National University
599-1 Daeyeon 3-dong, Nam-gu
Busan, 608-737
R Korea
francis@pknu.ac.kr

**Won Jai Maeng**
The Natural Sciences
The National Academy of Sciences Republic of Korea
12-1502 Sampoong Apt.
Seocho 4-dong Seocho-gu
Seoul, 137-779
R Korea
maengwj@gmail.com

**Jong-Hun Na**
Marine Production Management
Pukyong National University
599-1 Daeyeon 3-dong, Nam-gu
Busan, 608-737
R Korea
jhna@pknu.ac.kr

**Hye Min Park**
Department of Marine Biology
Pukyong National University
599-1 Daeyeon 3-dong, Nam-gu
Pusan, 608-737
R Korea
shrimppark@gmail.com

**Kwang-Seok Park**
Department of Environment Research
Research Institute of Industrial Science and Technology
32 San, Hyoja-dong, Nam-gu
Pohang, Gyeongbuk 790-330
R Korea
kspark@rist.re.kr

**Jung Hwa Ryu**
RJH Marine Research Institute
444-10 Gaya 3-dong
Busan, 614-803
R Korea
okdom-ryu@hanmail.net

**Umme Salma**
Department of Marine Biology
Pukyong National University
599-1 Daeyeon 3-dong, Nam-gu
Busan, 608-737
R Korea
ummesalma.bau@gmail.com

**Sinjae Yoo**
Marine Living Resources Division
Korea Ocean R&D Institute (KORDI)
1270 Sa-dong
Ansan, Gyeonggi-do 426-170
R Korea
sjyoo@kordi.re.kr

**Jin-Hee Yoon**
Department of Climate Change and Coastal Disaster Research
Korea Ocean R&D Institute (KORDI)
P.O. Box 29
Gyunggi-do, 425-600
R Korea
jiny.yoon@gmail.com

**Chang-Ik Zhang**
Marine Production Management
Pukyong National University
599-1 Daeyeon 3-dong, Nam-gu
Busan, 608-737
R Korea
cizhang@pknu.ac.kr

## *Malawi*

**Friday Jack Njaya**
Fisheries Policy and Planning
Malawi Fisheries Department
Ring Rd., Capital Hill
P.O. Box 593, Lilongwe, Malawi
Lilongwe, Central 593
Malawi
fnjaya@gmail.com

## *Malaysia*

**Edward Hugh Allison**
Policy, Economics and Social Science
The WorldFish Center
Jalan Batu Maung
Bayan Lepas, Penang 11960
Malaysia
e.allison@cgiar.org

**Marie-Caroline Badjeck**
The WorldFish Center
Jalan Batu Maung
P.O. Box 500
Penang, GPO 10670
Malaysia
m.badjeck@cgiar.org

**Mohamed Rawidean Kassim**
MIMOS
Technology Park Malaysia
Bukit Jalil
Kuala Lumpur, 57000
Malaysia
dean@mimos.my

## *México*

**Gastón Antonio Bazzino Ferreri**
Programa de Ecología Pesquera
CIBNOR S.C.
Mar Bermejo No.195, Colonia Playa Palo de Santa Rita
La Paz, Baja California Sur 23090
México
gbazzino04@cibnor.mx

**Salvador Emilio Lluch-Cota**
Fisheries Ecology
Centro de Investigaciones Biologicas del Noroeste (CIBNOR)
Mar Bermejo No. 195, Col. Playa Palo de Sta. Rita
La Paz, Baja California Sur 23000
México
slluch@cibnor.mx

**Rubén Rodríguez-Sánchez**
Pesquerias y Biologia Marina
Centro Interdisciplinario de Ciencias Marinas (CICIMAR)
Av. IPN s/n, Col. Palo de Sta. Rita, AP 592
La Paz, Baja California Sur 23090
México
rrodrig@ipn.mx

## New Caledonia

**Johann Bell**
Strategic Engagement, Policy and Planning Facility
Secretariat of the Pacific Community
B.P. D5
Noumea Cedex, 98848
New Caledonia
johannb@spc.int

**Timothy D. Pickering**
Coastal Fisheries Programme
Secretariat of the Pacific Community
B.P. D5, Ave. Roger Laroque
Noumea, 98848
New Caledonia
timp@spc.int

## New Zealand

**Rosemary J. Hurst**
National Institute of Water and Atmospheric Research Ltd.
301 Evans Bay Parade, Greta Point
Wellington, 6021
New Zealand
r.hurst@niwa.co.nz

## Nigeria

**Julius Ibukun Agboola**
Department of Fisheries
Lagos State University
Along Badagry Express-Way, Ojo,
P.O. Box 10409, Ikeja
Lagos, Lagos 2341
Nigeria
jb_agboola@yahoo.com

**Siyanbola A. Omitoyin**
Animal Science and Fisheries Management
Bowen University
8/9 Oluponna Road, PMB 284
Iwo, Osun State +234
Nigeria
sbomitoyin@yahoo.com

## Norway

**Mei-Yu Chang**
Department of Biology
UiB, Thormøhlensgate 53a (2 floor)
Bergen, 5020
Norway
meiyuchang0402@gmail.com

**Kenneth Drinkwater**
Institute of Marine Research
P.O. Box 1870, Nordnes, 33
Nordnesgaten
Bergen, N-5817
Norway
ken.drinkwater@imr.no

**Audrey J. Geffen (*Cancelled*)**
Department of Biology
University of Bergen
P.O. Box 7803
Bergen, 5020
Norway
audrey.geffen@bio.uib.no

**Manuel Hidalgo**
Department of Biology
University of Oslo
P.O.Box 1066, Blindern
Centre for Ecological and Evolutionary Synthesis
Oslo N-0316
Norway
manuel.hidalgo@bio.uio.no

**Solfrid S. Hjøllo**
Oceanography
Institute of Marine Research
Nordnesgaten 33
Bergen, 5817
Norway
Solfrid.Hjollo@imr.no

**Olav Sigurd Kjesbu**
Reproduction and Growth
Institute of Marine Research
P.O. Box 1870, Nordnes, 50
Nordnesgaten
Bergen, 5817
Norway
olav.kjesbu@imr.no

**Cecilie Kvamme**
Pelagic Fish
Institute of Marine Research
P.O. Box 1870 Nordnes
Bergen, N-5817
Norway
cecilie@imr.no

**Harald Loeng**
Institute of Marine Research
P.O. Box 1870 Nordnes
Bergen, 5817
Norway
harald.loeng@imr.no

**Benjamin Planque**
Institute of Marine Research
Postboks 6404
Tromsø, 9294
Norway
benjamin.planque@imr.no

**Svein Sundby**
Institute of Marine Research
Nordnesgaten 33
Bergen, N-5817
Norway
svein.sundby@imr.no

## Peru

**Luis Herrera Escudero**
Remote Sensing and GIS
Instituto del Mar del Peru
ESQ. Gamarra y Valle s/n, Chucuito
Lima, Callao 22
Peru
lescudero@imarpe.gob.pe

**Miguel Angel Niquen**
Pelagic Resource Area
Instituto del Mar del Perú (IMARPE)
Esquina Gamarra y General Valle s/n
Chucuito, Callao 22
Peru
mniquen@imarpe.gob.pe

## Philippines

**Maria Rebecca Alviar Campos**
Southeast Asian Regional Center for Graduate Studies and Research in Agriculture
10996 Campos Compound
Faculty Village, College
Laguna 4031
Philippines
cmaribec@yahoo.com

**Asuncion Bina De Guzman**
Institute of Fisheries Research and Development
Mindanao State University at Naawan
Poblacion, Naawan, Misamis
Oriental 9023
Philippines
sony_deguzman@yahoo.com

**Michael Dano Pido**
Center for Strategic Policy and Governance
Palawan State University
G/F Medical Bldg., Tiniguiban Heights
Puerto Princesa City
Palawan 5300
Philippines
mdpido@yahoo.com

## Portugal

**Ana Maria Moreira**
UREMS
INRB-IPIMAR
Av de Brasilia
Lisboa, 1449-006
Portugal
moreiratrue@gmail.com

**Jose Manuel Pereira da Silva (*Cancelled*)**
Ciencias Quimicas
Colegio Internato dos Carvalhos
Rua do Padrao, 83
Vila Nova de Gaia
Porto 4415-284 Pedroso
Portugal
zemanel@cic.pt

## Russia

**Nadezhda L. Aseeva**
Far-Eastern Seas Fisheries Resources
Pacific Research Institute of Fisheries and Oceanography (TINRO-Center)
4 Shevchenko Alley
Vladivostok, Primorsky Kray 690950
Russia
aseeva_n@hotmail.com

**Dmitry Galanin**
Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO)
196 Komsomolskaya St.
Yuzhno-Sakhalinsk, 693023
Russia
dmitry.galanin@yahoo.com

**Maxim Ishchenko**
V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS
43 Baltiyskaya St.
Vladivostok, Primorsky Kray 690041
Russia
maksim@poi.dvo.ru

**Dmitry D. Kaplunenko**
Department of Satellite Oceanology
V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS
43 Baltiyskaya St.
Vladivostok, Primorsky Kray 690041
Russia
dimkap@poi.dvo.ru

**Talgat R. Kilmatov**
Pacific State University of Economics
19 Okeansky Pr.
Vladivostok, Primorsky Kray 690950
Russia
talgat_k@mail.ru

**Aleksey V. Koldunov**
Laboratory of Regional Oceanography
St. Petersburg State University
10 Line of Vasilievsky Island 33-35
St. Petersburg, 199178
Russia
koldunovaleksey@gmail.com

**Andrei S. Krovnin (*Cancelled*)**
Laboratory of Climatic Bases of Bioproductivity
Russian Federal Research Institute of Fisheries and Oceanography (VNIRO)
17 V. Krasnoselskaya St.
Moscow, 107140
Russia
akrovnin@vniro.ru

**Tatyana N. Krupnova**
Pacific Research Institute of Fisheries and Oceanography (TINRO-Centre)
4 Shevchenko Alley
Vladivostok, Primorsky Kray 690950
Russia
krupnova@tinro.ru

**Svetlana A. Murzina**
Environmental Biochemistry
Institute of Biology
Karelian Research Centre Russian Academy of Science
11 Pushkinskaya St.
Petrozavodsk, 185910
Russia
imagination@onego.ru

**Boris Prischepa**
Knipovitch Polar Research Institute of Marine Fisheries and Oceanography
6 Knipovich St.
Murmansk, 183763
Russia
inter@pinro.ru

**Sergey Prusov**
Freshwater Resources Laboratory
Knipovitch Polar Research Institute of Marine Fisheries and Oceanography
6 Knipovich St.
Murmansk, 183763
Russia
prusov@pinro.ru

**Konstantin A. Rogachev**
Department of Ocean Physics
V.I. Il´ichev Pacific Oceanological Institute (POI), FEB RAS
43 Baltiyskaya St.
Vladivostok, Primorsky Kray 690041
Russia
rogachev@poi.dvo.ru

**Elena I. Ustinova**
Laboratory of Fisheries Oceanography
Pacific Research Institute of Fisheries and Oceanography (TINRO-Center)
4 Shevchenko Alley
Vladivostok, Primorsky Kray 690950
Russia
eustinova@mail.ru

**Alexey V. Vakatov**
Laboratory of Commercial Marine Fish
Magadan Reseach Institute of Fishery and Oceanography
36/10 Portovaya
Magadan, 685000
Russia
alexvakatov@mail.ru

**Anatoliy Velikanov**
State Committe for Fisheries of the Russian Federation
Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO)
196 Komsomolskaya St.
Yuzhno-Sakhalinsk, Sakhalin 693023
Russia
velikanov@sakhniro.ru

**Yury I. Zuenko**
Japan Sea and North-West Pacific Oceanography
Pacific Research Institute of Fisheries and Oceanography (TINRO-Center)
4 Shevchenko Alley
Vladivostok, Primorsky Kray 690950
Russia
zuenko_yury@hotmail.com

## South Africa

**Janet Clare Coetzee**
Department of Environmental Affairs
Marine and Coastal Management
Foretrust House
Martin Hammerschlag Rd.
Cape Town, 8102
South Africa
jcoetzee@deat.gov.za

**Warwick Sauer**
Department of Ichthyology and Fisheries Science
Rhodes University
P.O. Box 94
Grahamstown, 6140
South Africa
w.sauer@ru.ac.za

**Nandipha Monica Twatwa**
Department of Environmental Affairs
Marine and Coastal Management
Martin Hammerschlarg Way
Foretrust Building, Foreshore
Cape Town, Western Cape 7708
South Africa
Natwatwa@deat.gov.za

**Kate Eleanor Watermeyer**
Department of Zoology
University of Cape Town
Zoology Department
Private Bag X3
Rondebosch, 770
Cape Town, Western Cape 7701
South Africa
kwatermeyer@gmail.com

**Dawit Yemane**
Department of Environmental Affairs
Marine and Coastal Management
Foretrust House
Martin Hammerschlag Rd.
Cape Town, 8012
South Africa
dawityemane@gmail.com

## Spain

**Eider Andonegi**
Marine Research Division
AZTI-Tecnalia
Txatxarramendi ugartea z/g
Sukarrieta, Bizkaia 48395
Spain
eandonegi@azti.es

**Miguel Bernal**
C.O. de Cádiz
Instituto Español de Oceanografía
Puerto Pesquero
Muelle de Levante, s/n Cádiz
Cádiz 11006
Spain
miguel.bernal@cd.ieo.es

**Sebastian Villasante**
Av Burgo das Nacions s/n
Santiago de Compostela
A Coruña 15782
Spain
sebastian.villasante@usc.es

## Sweden

**Valerio Bartolino**
Institute of Marine Research
Swedish Board of Fisheries
Turistgatan 5
Lysekil, 54321
Sweden
valerio.bartolino@uniroma1.it

**Susa Niiranen**
Stockholm Resilience Centre
Baltic Nest Institute
Kräftriket 10
Stockholm University
Stockholm, SE-106 91
Sweden
sniir@mbox.su.se

**Sujan Saha**
Independent Researcher
c/o M. Chowdhury, Tings Vägen
21 TR 2, 145-56 Norsberg
Stockholm, 145-56
Sweden
sujan407@yahoo.com

## Thailand

**Siraprapha Premcharoen**
Department of Science
Kasetsart University
Faculty of Liberal Arts and Science, Kamphaeng Saen
Nakhon Pathom, 73140
Thailand
faassrp@hotmail.com

## The Netherlands

**Remment ter Hofstede**
Department of Ecology
IMARES (Institute for Marine Resources and Ecosystem Studies)
P.O. Box 68
IJmuiden, 1970 AB
The Netherlands
remment.terhofstede@wur.nl

**Ralf van Hal**
Department of Ecology
IMARES (Institute for Marine Resources and Ecosystem Studies)
Haringkade 1
IJmuiden, Noord-Holland 1973 RR
The Netherlands
ralf.vanhal@wur.nl

## Tunisia

**Frida Ben Rais Lasram**
Aquatic Resources and Ecosystems
National Agronomic Institute of Tunisia
43 Avenue Charles Nicolle
Tunis, 1082
Tunisia
frida.lasram@gmail.com

## U.S.A.

**Melanie Abecassis**
Ecosystems and Oceanography Division
JIMAR/PIFSC
2570 Dole St.
Honolulu, HI 96822
U.S.A.
melanie.abecassis@noaa.gov

**Teresa A'mar**
Resource Ecology and Fisheries Management Division
NOAA Fisheries
F/AKC2, 7600 Sand Point Way NE
Seattle, WA 98115
U.S.A.
Teresa.Amar@noaa.gov

**Rebecca Asch**
Integrative Oceanography Division
Scripps Institution of Oceanography
9500 Gilman Dr.
Mail Code 0208
La Jolla, CA 92093-0208
U.S.A.
rgasch@ucsd.edu

**Elizabeth Atwood**
Quantitative Ecology and Resource Management
University of Washington
1122 NE Boat St.
Seattle, WA 98195-5020
U.S.A.
eatwood@u.washington.edu

**Nicholas A. Bond**
Joint Institute for the Study of Atmosphere and Ocean (JISAO)
University of Washington
7600 Sand Point Way NE
NOAA/PMEL
Seattle, WA 98195-4925
U.S.A.
nicholas.bond@noaa.gov

**Louis W. Botsford**
Wildlife, Fish and Conservation Biology
University of California at Davis
1 Shields Ave.
Davis, CA 95616
U.S.A.
lwbotsford@ucdavis.edu

**Jon Kenton Tarsus Brodziak**
Fish Biology and Stock Assessment
Pacific Islands Fisheries Science Center, NMFS, NOAA
PIFSC, 2570 Dole St.
Honolulu, HI 96822
U.S.A.
jon.brodziak@noaa.gov

**David M. Checkley**
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Dr.
La Jolla, CA 92093-0218
U.S.A.
dcheckley@ucsd.edu

**Michelle Cho**
Department of Conservation
New England Aquarium
Central Wharf
Boston, MA 02110
U.S.A.
mcho@neaq.org

**Enrique N. Curchitser**
Institute of Marine and Coastal Sciences
Rutgers University
71 Dudley Rd.
New Brunswick, NJ 08901
U.S.A.
enrique@marine.rutgers.edu

**Michael J. Dagg**
Louisiana Universities Marine Consortium
8124 Hwy 56
Chauvin, LA 70344
U.S.A.
mdagg@lumcon.edu

**Gerard DiNardo**
Pacific Islands Fisheries Science Center, NMFS, NOAA
2570 Dole St.
Honolulu, HI 96822
U.S.A.
Gerard.DiNardo@noaa.gov

**Michele Longo Eder**
North Pacific Reasearch Board
1007 West 3rd Ave.
Anchorage, AK 22203
U.S.A.
michele@michelelongoeder.com

**Lisa B. Eisner**
TSMRI/Auke Bay Laboratories
Alaska Fisheries Science Center
NMFS, NOAA
17109 Pt. Lena Loop Rd.
Juneau, AK 99801
U.S.A.
lisa.eisner@noaa.gov

**Edward W. Farley**
DOC
NOAA/NMFS/AFSC
17109 Pt. Lena Loop Rd.
Juneau, AK 99801
U.S.A.
ed.farley@noaa.gov

**John Robert Gauvin**
Best Use Cooperative
4241 21st Ave. West
Suite 302
Seattle, WA 98199
U.S.A.
gauvin@seanet.com

**Rini Ghosh (*Cancelled*)**
International Fisheries Program
NOAA NMFS PIRO
1601 Kapiolani Blvd., Suite 1110
Honolulu, HI 96814
U.S.A.
rini.ghosh@noaa.gov

**Georgina Gibson**
International Arctic Research Center
University of Alaska Fairbanks
930 Koyukuk Dr.
Fairbanks, AK 99775-7340
U.S.A.
ggibson@iarc.uaf.edu

**Karen Gillis**
Bering Sea Fishermen's Association
110 West 15th Ave., Suite A
Anchorage, AK 99501
U.S.A.
karen.gillis@bsfaak.org

**Anand Gnanadesikan**
Oceans and Climate Group Group
NOAA Geophysical Fluid Dynamics Laboratory
Princeton University Forrestal Campus
201 Forrestal Rd.
Princeton, NJ 08540-6649
U.S.A.
Anand.Gnanadesikan@noaa.gov

**Melissa A. Haltuch**
Northwest Fisheries Science Center, NMFS, NOAA
2725 Montlake Blvd. E
Seattle, WA 98112-2097
U.S.A.
melissa.haltuch@noaa.gov

**Jonathan Hare**
Narragansett Laboratory
NOAA NEFSC NMFS
28 Tarzwell Dr.
Narragansett, RI 02882
U.S.A.
jon.hare@noaa.gov

**Alan C. Haynie**
Alaska Fisheries Science Center
NOAA Fisheries
7600 Sand Point Way NE, Bldg. 4
Seattle, WA 98115
U.S.A.
Alan.Haynie@noaa.gov

**Katherine Hedström**
Arctic Region Supercomputing Center
University of Alaska Fairbanks
909 Koyukuk Dr., Suite 105
Fairbanks, AK 99775
U.S.A.
kate@arsc.edu

**Albert J. Hermann**
Joint Institute for the Study of Atmosphere and Ocean (JISAO)
University of Washington
7600 Sand Point Way NE
NOAA/PMEL
Seattle, WA 98115
U.S.A.
Albert.J.Hermann@noaa.gov

**Anne B. Hollowed**
Alaska Fisheries Science Center
NMFS, NOAA
7600 Sand Point Way NE
Seattle, WA 98115-6349
U.S.A.
Anne.Hollowed@noaa.gov

**Howard Horton**
Fisheries and Wildlife
Oregon State University
104 Nash Hall
Corvallis, OR 97331
U.S.A.
hortonho@onid.orst.edu

**Evan A. Howell**
Ecosystems and Oceanography Division
Pacific Islands Fisheries Science Center, NMFS, NOAA
2570 Dole St.
Honolulu, HI 96822
U.S.A.
evan.howell@noaa.gov

**George L. Hunt, Jr.**
School of Aquatic and Fishery Sciences
University of Washington
P.O. Box 355020
Seattle, WA 98195
U.S.A.
geohunt2@u.washington.edu

**Henry P. Huntington**
Arctic Program
Pew Environment Group
23834 The Clearing Dr.
Eagle River, AK 99577
U.S.A.
hhuntington@pewtrusts.org

**James N. Ianelli**
Resource Ecology and Fisheries Management
Alaska Fisheries Science Center
NMFS, NOAA
7600 Sand Point Way NE
Seattle, WA 98115
U.S.A.
Jim.Ianelli@noaa.gov

**Felix Jose (*Cancelled*)**
Coastal Studies Institute
Louisiana State University
CSI, How-Russell GeoSciences Complex
Baton Rouge, LA 70803
U.S.A.
felixjose@lsu.edu

**John Tillman Lamkin**
Southeast Fisheries Science Center
NOAA-Fisheries
75 Virginia Beach Dr.
Miami, FL 33149
U.S.A.
John.Lamkin@noaa.gov

**Hui-Hua Lee**
2570 Dole St.
Honolulu, HI 96822
U.S.A.
huihua.lee@noaa.gov

**Paul William MacGregor**
General Counsel
At-sea Processors Association
4005 20th Ave. West, Suite 115
Seattle, WA 98199
U.S.A.
pmacgregor@mundtmac.com

**Bonnie J. McCay**
Human Ecology
Rutgers University
55 Dudley Rd.
New Brunswick, NJ 08901
U.S.A.
mccay@aesop.rutgers.edu

**Bernard A. Megrey**
Alaska Fisheries Science Center
NMFS, NOAA
7600 Sand Point Way NE
Seattle, WA 98115-6349
U.S.A.
Bern.Megrey@noaa.gov

**Jennifer L. Menkel**
Cooperative Institute for Marine Resources Studies, HMSC
Oregon State University
2030 SE Marine Science Dr.
Newport, OR 97365
U.S.A.
jennifer.menkel@oregonstate.edu

**Cheryl A. Morgan**
Cooperative Institute for Marine Resources Studies, HMSC
Oregon State University
2030 SE Marine Science Dr.
Newport, OR 97365
U.S.A.
cheryl.morgan@oregonstate.edu

**Franz J. Mueter**
School of Fisheries and Ocean Sciences, Juneau Center
University of Alaska Fairbanks
17109 Pt. Lena Loop Rd.
Juneau, AK 99801
U.S.A.
fmueter@alaska.edu

**Barbara Muhling**
National Marine Fisheries Service
75 Virginia Beach Dr.
Miami, FL 33149
U.S.A.
Barbara.Muhling@noaa.gov

**Phillip R. Mundy**
Auke Bay Laboratories/TSMRI
Alaska Fisheries Science Center
NMFS, NOAA
17109 Pt. Lena Loop Rd.
Juneau, AK 99801
U.S.A.
Phil.mundy@noaa.gov

**Steven A. Murawski**
Office of the Assistant Adminstrator
NOAA Fisheries Service
1315 East West Hwy, SSMC#
Room 14659
Silver Spring, MD 20910-3282
U.S.A.
Steve.Murawski@noaa.gov

**Jeffrey M. Napp**
Alaska Fisheries Science Center
NMFS, NOAA
7600 Sand Point Way NE
Seattle, WA 98115-6349
U.S.A.
Jeff.Napp@noaa.gov

**Jennifer L. Nielsen**
Department of Biology
USGS
4210 University Dr.
Anchorage, AK 99508
U.S.A.
jlnielsen@usgs.gov

**Paul E. Niemeier**
Office of International Affairs
NMFS, NOAA
1315 East-West Highway
SSMC3, Room 12752
Silver Spring, MD 20910
U.S.A.
paul.niemeier@noaa.gov

**Janet A. Nye**
NOAA NMFS NFSC
166 Water St.
Woods Hole, MA 02543
U.S.A.
janetnye@gmail.com

**Eric A. Olson**
North Pacific Research Board
1016 West 6th Avenue, Suite 301
Anchorage, Alaska 99501
U.S.A.
eolson@gci.net

**Ivonne Ortiz**
Alaska Fisheries Science Center
NMFS, NOAA
7600 Sand Point Way NE, Bldg. 4
Seattle, WA 98115
U.S.A.
ivonne@u.washington.edu

**James E. Overland**
Pacific Marine Environmental Laboratory, NOAA
7600 Sand Point Way NE
Seattle, WA 98115-6349
U.S.A.
James.E.Overland@noaa.gov

**Clarence Pautzke**
Executive Director
North Pacific Research Board (NPRB)
1007 W. 3rd Ave., Suite 100
Anchorage, AK 99501
U.S.A.
cpautzke@nprb.org

**Jay Peterson**
Cooperative Institute for Marine Resources Studies, HMSC
Oregon State University
2030 SE Marine Science Dr.
Newport, OR 97365
U.S.A.
jay.peterson@oregonstate.edu

**William T. Peterson**
Cooperative Institute for Marine Resources Studies, HMSC
Oregon State University
2030 SE Marine Science Dr.
Newport, OR 97365
U.S.A.
Bill.Peterson@noaa.gov

**Kevin Piner**
NOAA Fisheries
2570 Dole St.
Honolulu, HI 96822
U.S.A.
kevin.piner@noaa.gov

**Jeffrey J. Polovina**
Ecosystems and Oceanography Division
Pacific Islands Fisheries Science Center, NMFS, NOAA
2570 Dole St.
Honolulu, HI 96822
U.S.A.
Jeffrey.Polovina@noaa.gov

**Samuel G. Pooley**
NOAA Fisheries
Pacific Islands Fisheries Science Center, NMFS, NOAA
2570 Dole St.
Honolulu, HI 96822-2396
U.S.A.
samuel.pooley@noaa.gov

**Thomas E. Reed**
School of Aquatic and Fishery Sciences
University of Washington
Box 355020, 1122 NE Boat St.
Seatlle, WA 98105
U.S.A.
tomreed@uw.edu

**Deborah A. Reusser**
USGS-Western Fisheries Research Center at Marine Hatfield Science Center
2111 SE Marine Science Dr.
Newport, OR 97365
U.S.A.
dreusser@usgs.gov

**Kenneth A. Rose**
Oceanography and Coastal Sciences
Louisiana State University
3125 Energy, Coast, and Environment Bldg.
Baton Rouge, LA 70803
U.S.A.
karose@lsu.edu

**Brian J. Rothschild**
School for Marine Science and Technology
University of Massachusetts Dartmouth
706 South Rodney French Blvd.
New Bedford, MA 02744-1221
U.S.A.
brothschild@umassd.edu

**Steve S. Rumrill**
Department of Biology
University of Oregon
63466 Boat Basin Dr.
Charleston, OR 97420
U.S.A.
Steve.Rumrill@state.or.us

**Ryan R. Rykaczewski**
Geophysical Fluid Dynamics Laboratory
University Corporation for Atmospheric Research
Princeton University Forrestal Campus, 201 Forrestal Rd.
Princeton, NJ 08540-6649
U.S.A.
ryan.rykaczewski@noaa.gov

**Kehinde Salau**
Applied Mathematics for the Life and Social Sciences
Arizona State University
2430 South Mill Ave., Apt. 108
Tempe, AZ 85282
U.S.A.
kehinde.salau@gmail.com

**Jameal Samhouri**
Northwest Fisheries Science Center
NOAA Fisheries
2725 Montlake Blvd. E
Seattle, WA 98112
U.S.A.
jameal.samhouri@noaa.gov

**Michael J. Schirripa**
Sustainable Fisheries Division
Southeast Fisheries Science Centre, NMFS, NOAA
Hatfield Marine Science Centre
75 Virginia Beach Dr.
Miami, FL 33149
U.S.A.
Michael.Schirripa@noaa.gov

**Franklin B. Schwing**
Environmental Research Division
Southwest Fisheries Science Center
NMFS, NOAA
1352 Lighthouse Ave.
Pacific Grove, CA 93950
U.S.A.
franklin.schwing@noaa.gov

**C. Tracy Shaw**
Cooperative Institute for Marine Resources Studies, HMSC
Oregon State University
2030 SE Marine Science Dr.
Newport, OR 97365
U.S.A.
tracy.shaw@noaa.gov

**Michael Simpkins (*Cancelled*)**
Office of International Affairs
NOAA Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910
U.S.A.
Michael.Simpkins@noaa.gov

**John E. Stein**
Northwest Fisheries Science Center
NMFS, NOAA
2725 Montlake Blvd. E
Seattle, WA 98112-2097
U.S.A.
John.E.Stein@noaa.gov

**Charles A. Stock**
NOAA Geophysical Fluid Dynamics Laboratory
Princeton University Forrestal Campus, 201 Forrestal Rd.
Princeton, NJ 08540-6649
U.S.A.
charles.stock@noaa.gov

**Andrei V. Suntsov**
Integrative Oceanography Division
Scripps Institution of Oceanography, UCSD
9500 Gilman Dr.
La Jolla, CA 92093-0218
U.S.A.
asuntsov@mail.ru

**Satsuki Takahashi**
Department of Anthropology
Rutgers University
131 George St.,
New Brunswick,
NJ 08901-1414
USA
satsuki@eden.rutgers.edu

**Erica McCall Valentine**
Community Ecosystem Services
Ecotrust
P.O. Box 868
Talkeetna, AK 99676
U.S.A.
evalentine@ecotrust.org

**Juan L. Valero**
International Pacific Halibut Commission
P.O. Box 95009
Seattle, WA 98145-2009
U.S.A.
juan@iphc.washington.edu

**Thomas Van Pelt**
North Pacific Research Board
1007 West Third Ave., Suite 100
Anchorage, AK 99501
U.S.A.
tvanpelt@nprb.org

**Alyson Marie Venti**
Marine and Atmospheric Chemistry
University of Miami
Rosenstiel School of Marine and Atmospheric Science
4600 Rickenbacker Cswy
Miami, FL 33149
U.S.A.
aventi@rsmas.miami.edu

**Lyn Mie Wagatsuma**
Research Corporation of the University of Hawaii
Joint Institute for Marine and Atmospheric Research
2570 Dole St.
Honolulu, HI 96822
U.S.A.
Lyn.Wagatsuma@noaa.gov

**Thomas C. Wainwright**
Northwest Fisheries Science Center
NOAA Fisheries
2032 SE OSU Dr.
Newport, OR 97365-5296
U.S.A.
thomas.wainwright@noaa.gov

**Muyin Wang**
Joint Institute for the Study of Atmosphere and Ocean (JISAO)
University of Washington
7600 Sand Point Way NE
Seattle, WA 98115
U.S.A.
muyin.wang@noaa.gov

**Lawrence Wasserman**
Department of Planning
Swinomish Indian Tribal Community
11430 Moorage Way
LaConner, WA 98257
U.S.A.
lwasserman@skagitcoop.org

**Francisco E. Werner**
Institute of Marine and Coastal Sciences
Rutgers University
71 Dudley Rd.
New Brunswick, NJ 08901
U.S.A.
cisco@marine.rutgers.edu

**Francis Karl Wiese**
North Pacific Research Board (NPRB)
1007 West 3rd Ave., Suite 100
Anchorage, AK 99501
U.S.A.
francis.wiese@nprb.org

**Matthew T. Wilson**
Alaska Fisheries Science Center,
NMFS, NOAA
7600 Sand Point Way NE
Seattle, WA 99115-6349
U.S.A.
matt.wilson@noaa.gov

## Ukraine

**Alexandra V. Temnykh**
Department of Biophysical Ecology
Institute of Biology of the
Southern Seas
Nakhimov Ave. 2
Sevastopol, 99011
Ukraine
atemnykh@rambler.ru

## United Kingdom

**Julian Icarus Allen**
Plymouth Marine Laboratory
Prospect Place
Plymouth, PL1 3DH
United Kingdom
jia@pml.ac.uk

**Alexander Arkhipkin**
Fisheries Department
Falkland Islands Government
FIPASS
Stanley, FIQQ 1ZZ
United Kingdom
aarkhipkin@fisheries.gov.fk

**Manuel Barange**
Plymouth Marine Laboratory
Prospect Place
Plymouth, Devon PL1 3DH
United Kingdom
m.barange@pml.ac.uk

**Julia L. Blanchard**
Division of Biology
Imperial College London
Silwood Park Campus, Buckhurst Rd.
Ascot, Berkshire SL5 7PY
United Kingdom
j.blanchard@imperial.ac.uk

**William L. Cheung**
School of Environmental Sciences
University of East Anglia
Norwich, Norfolk NR4 7TJ
United Kingdom
william.cheung@uea.ac.uk

**Rob Holmes**
Plymouth Marine Laboratory
Prospect Place
Plymouth, Devon PL1 3DH
United Kingdom
robe1@pml.ac.uk

**Jason Holt**
Proudman Oceanographic Laboratory
6 Brownlow St., Joseph Proudman Bldg.
Liverpool, L3 5DA
United Kingdom
jholt@pol.ac.uk

**Gorka Merino**
Plymouth Marine Laboratory
Prospect Place, The Hoe
Plymouth, Devon PL1 3DH
United Kingdom
gmerin@pml.ac.uk

**Graham M. Pilling**
Centre for Environment, Fisheries
& Aquaculture Science (CEFAS)
Pakefield Rd.
Lowestoft, Suffolk NR33 0HT
United Kingdom
patricia.marsh@cefas.co.uk

**John K. Pinnegar**
Centre for Environment, Fisheries
& Aquaculture Science (CEFAS)
Pakefield Rd.
Lowestoft, Suffolk NR33 0HT
United Kingdom
john.pinnegar@cefas.co.uk

**Mark Prime**
Centre for Environmental and
Marine Sciences
University of Hull - Scarborough
Campus, Filey Rd.
Scarborough, YO11 3AZ
United Kingdom
mark.prime@gmail.com

**Joe Scutt-Phillips**
Centre for Environment, Fisheries
& Aquaculture Science (CEFAS)
Pakefield Rd.
Lowestoft, Suffolk NR33 0HT
United Kingdom
joe.scuttphillips@cefas.co.uk

**Stephen D. Simpson**
School of Biological Sciences
University of Bristol
Woodland Rd.
Bristol, BS8 1UG
United Kingdom
Stephen.Simpson@bristol.ac.uk

## Vietnam

**Nguyen Huu Ninh**
Vietnam National University
279/24 Giang Vo St.
Hanoi, 144
Vietnam
nguyen.huuninh@yahoo.com

**Hien Thi Than**
Research and Development
Centre for Marinelife Conservation and
Community Development (MCD)
Suite 3104, Level 31, Bldg. 34T
Hoang Dao Thuy St.,
Hanoi, 84-4, Vietnam
tthien@mcdvietnam.org

**Du Van Toan**
Department of Marine Resources
Management and CC
Research Institute for Management
of Sea and Islands
83 Nguyen Chi Thanh Rd.
Hanoi 84
Vietnam
duvantoan@gmail.com