

Phase 3

Summary of the PICES Workshop on
Linking Global Climate Model Output to (a) Trends in Commercial Species Productivity and
(b) Changes in Broader Biological Communities in the World's Oceans

May 18, 2008
Gijón, Spain

A workshop entitled *Linking Global Climate Model Output to (a) Trends in Commercial Species Productivity and (b) Changes in Broader Biological Communities in the World's Oceans* was convened on May 18, 2008, at the ICES/PICES/IOC International Symposium on the “*Effects of Climate Change on the World's Oceans*” in Gijón, Spain. The workshop had the ultimate goal of facilitating a coordinated international research effort to forecast climate change impacts on the distribution and production of the world's major fisheries, and on the biological communities in which these fisheries are embedded. It was attended by 33 people from 13 nations (see Appendix 3.1) and there was consensus that this group could initiate a coordinated international collaboration to advance research in marine climate impacts. Two originally proposed workshops entitled, “*Linking Climate to Trends in Productivity of Key Commercial Species in the World's Oceans*” and “*Screening Approaches and Linking Global Climate Model Output with Ecosystem and Population Models*” were combined by the convenors because they were complementary. In retrospect, blending the two “schools” was fortuitous as it placed us in a better-than-expected position to initiate an effective international collaboration.

The specific objectives were to:

- review the activities of existing programs within each nation;
- examine evidence for climate impacts on production of commercial fish species and other marine life;
- discuss the feasibility of developing medium- to long-term forecasts of climate impacts;
- discuss possible responses of commercial fisheries, human communities, and governments to climate-driven changes in marine life; and
- identify common or standard approaches to forecasting climate change impacts on commercial species and marine communities and ecosystems.

Workshop participants discussed climate scenarios to use in forecasting and the tools required for predicting climate impacts on commercial fish production and broader marine ecosystems. The workshop provided a forum to discuss four components needed to complete the forecasts in a timely and coordinated fashion. These included Intergovernmental Panel on Climate Change (IPCC) scenarios, predictions of oceanographic impacts,

modeling approaches, and regional scenarios for natural resource use and enhancement. The ecosystem component of the workshop surveyed a wide variety of approaches such as vulnerability assessments for informing location choices for ecosystem modeling efforts and management prioritization, trophodynamic fishery ecosystem modeling (*i.e.*, Ecopath with Ecosim), climate envelope modeling, statistical approaches, and three-dimensional high-resolution biogeochemical ecosystem modeling (*i.e.*, CCC-NEMURO).

The workshop began with an introduction by Anne Hollowed (U.S.A.) who proposed: (1) an overarching goal of producing quantitative estimates of climate change effects on the marine ecosystem – biology – in the next 5 years; (2) a review of all the related international efforts in a paper that would lay out a path for collaboration development; (3) initiation of a coordinated international effort — broader than one basin; and (4) production of a special journal issue for showcasing forecasting approaches that are available and are being developed. She discussed three broad approaches representing different levels of advancement in the science of climate impacts forecasting, listed in increasing order of sophistication:

1. IPCC scenarios downscaled to local regions and ecosystem indicators used to project future fish production using detailed management strategy evaluations;
2. IPCC scenarios downscaled to local regions and coupled to bio-physical models with higher trophic level feedbacks;
3. Fully coupled bio-physical models that operate at time and space scales relevant to coastal domains.

The main program of the workshop (Appendix 3.2) started with a round-table discussion of existing national or international projects developing forecasting initiatives, including Quest-FISH (Jason Holt), Fisheries and the Environment (FATE; Anne Hollowed), PICES' Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems (FUTURE; Michael Foreman), North Pacific Research Board Bering Sea Integrated Ecosystem Research Program (NPRB BSIERP; Clarence Pautzke), Climate Impacts on Oceanic Top Predators (CLIOTOP; Alistair Hobday), Ecosystem Studies of Sub-Arctic Seas (ESSAS; Harald Loeng), Evidencias e Impacto do Cambio Climático en Galicia (CLIGAL; Antonio Bode) and initiatives by the New Zealand Ministry of Fisheries (Mary Livingston).

The rest of the morning was devoted to eight presentations of projects that linked Global Climate Model (GCM) output to trends in commercial species productivity.

Nicholas Bond (U.S.A.) presented “*A method for using IPCC model simulations to project changes in marine ecosystems*” in which he compared ensembles of hindcasted atmosphere–ocean model output to observed measurements, and used a tiered statistical approach to select a subset of models that performed well in representing regional oceanographic projections. This work indicated that different models have different strengths, so a particular question should use a tailored subset of models.

Mary Livingston (New Zealand) presented “*Climate change, oceanic response and possible effects on fish stocks in New Zealand waters*” in which she described how climate change-related ecological trends have been equivocal in New Zealand during the last 50 years due to its oceanographic and ecological uniqueness and complexity and the paucity of long time series. Some of New Zealand’s marine life might be quite vulnerable to climate and oceanographic changes due to a variety of factors, and thus there are plans to integrate climate impacts studies with marine fisheries research and management.

Jae Bong Lee (Republic of Korea) presented “*Forecasting climate change impacts on distribution and abundance of jack mackerel around Korean waters*” in which he illustrated how variations in ocean conditions and warming of ocean water around Korea has influenced the distributions of jack mackerel in terms of their seasonal visitation to Korean waters from the East China Sea, and suggested that continued warming by 2100 may have considerable effects on these stocks around Korea. Future sea surface temperature, ocean drift and other oceanographic variables projected with GCMs will be incorporated into a stock projection model to forecast future production scenarios.

Sukyung Kang (Republic of Korea) presented “*Techniques for forecasting climate-induced variation in the distribution and abundance of mackerels in the Northwestern Pacific*” in which she described an exploration of the positive relationship between mackerel production and warm ocean conditions and progress in forecasting the impact of

climate change on mackerel production by downscaling forecasts of atmosphere–ocean conditions from GCMs to drive stock projection models.

Adriaan Rijnsdorp (The Netherlands) presented “*Effects of climate change on sole and plaice: Timing of spawning, length of the growth period and rate of growth*” in which he reviewed how increased temperatures since 1989 in coastal nursery grounds in the southeastern North Sea has had a negative impact on plaice and a positive effect on sole thus causing a shifting species composition as their habitat quality changes. Implications of physiological trade-offs in this changing system will make forecasting challenging.

Z. Teresa A’mar (U.S.A.) presented “*The impact on management performance of including indicators of environmental variability in management strategies for the Gulf of Alaska walleye pollock fishery*” in which she provided her management strategy evaluation (MSE) of the Gulf of Alaska walleye pollock fishery, with multiple indices of climate forcing incorporated into her overall modelling framework. The best performing management strategies were ones that were more responsive to fluctuations in productivity due to environmental influences.

Michael Schirripa (U.S.A.) presented “*Simulation testing two methods of including environmental data into stock assessments*” in which he described the development of environmental indicators of fish stock recruitment and provided both modelling and a statistical examples of how such indicators could be used in stock assessments and forecasting. Sea surface height (SSH) was the best predictor of recruitment in this analysis, as low SSH occurs when the California Current and upwelling are both strong, and this is associated with high productivity.

Alan Haynie (U.S.A.) presented “*Climate change and changing fisher behavior in the Bering Sea pollock fishery*” in which he discussed how fishermen will respond to changes in fish abundance driven by climate change, and that this will, in turn, have an impact on the ecosystem. The fisheries we observe today result from current stock distributions, abundances, and prices — all of these will change with climate. Spatial and market regulations that consider the relationship between fishermen and the

environment as the climate changes will be most effective.

The morning session concluded with a discussion of the presentations and the outlook for forecasting commercial fisheries.

Thomas Okey, Pew Fellow in Marine Conservation, introduced the afternoon session by providing a framework highlighting complementary modelling approaches that could be used to explore climate impacts on marine biota and ecosystems. He described conceptual and qualitative models that are useful for proactive decision-making as a segue to the more quantitative approaches to linking GCM output to changes in broader marine communities.

Jorge Sarmiento (U.S.A.) presented “*Modeling response of ocean biology to climate warming using an empirical approach*” in which he compared global warming simulations from six climate models and the physical changes projected for six ocean biomes. All six models indicated increases in primary production at high latitudes, but the models did not agree with direction of change at mid-latitudes.

Taketo Hashioka (Japan) presented “*Future ecosystem changes projected by a 3-D high-resolution ecosystem model*” in which he described efforts to develop a high-resolution ecosystem model by linking COCO (CCSR Ocean Component Models) to NEMURO and NEMURO.FISH models. Projections included a 30% decrease in the Kuroshio, 10–30% decreases in Chl-*a*, a shift from diatoms to small phytoplankton, spring bloom 10 days earlier, decreases in phytoplankton biomass by 25%, and a 2° shift in the distribution of sardines.

William Cheung (Canada) presented a “*Dynamic bio-climate envelope model to predict climate-induced changes in distribution of marine fishes and invertebrates*” in which he provided a global assessment of climate-induced range shifts of 1066 commercial species throughout the world’s oceans from changing temperature, habitat characteristics, and other mediators of dispersal and range occupation.

Alistair Hobday (Australia) presented “*Informing location choices for ecosystem model development using a vulnerability index*” as an Australian example of a quantitative vulnerability assessment that is used to identify the ecosystems, habitats,

biological components, and human values most vulnerable to projected climate change so that climate impacts modelling and monitoring can be prioritized and targeted efficiently. The CSIRO Mk 3.5 model projections to 2070 provided indicators of climate change, while non-climate indicators were derived from other Australian data sets.

Simone Libralato (Italy) presented “*Towards the integration of biogeochemical and food web models for a comprehensive description of marine ecosystem dynamics*” in which he reviewed the progress and outlooks for achieving end-to-end modelling (e.g., from viruses to fishes, from nutrients to fisheries, including climatic changes) by linking biogeochemical models with trophodynamic models. He also summarized outcomes of the 2007 Trieste (Italy) workshop on “*Biogeochemical processes and fish dynamics in food web models for end-to-end conceptualisation of marine ecosystems: theory and use of Ecopath with Ecosim*”.

Steven Mackinson (U.K.) presented “*Which forcing factors fit? Using ecosystem models to investigate the relative influence of fishing and primary productivity on the dynamics of marine ecosystems*” in which he described dynamic fitting with Ecopath with Ecosim models to identify the main driving forces of fish stocks and marine ecosystems (e.g., fishing mortalities or proxies of primary production), to assess the relative importance of these factors across regions, and to evaluate whether similar groups in different ecosystems respond similarly.

Sheila Heymans (U.K.) presented “*The effects of climate change on the northern Benguela ecosystem*” in which she simulated the effect of global warming on the northern Benguela Current system by fitting a 1956 Ecopath with Ecosim model to 2000 conditions and then simulating 50 years of sea surface temperature rise. The ecological effects were evaluated by indices of ecosystem function and commercial gain.

The case studies presented during this workshop indicated the variety of approaches (and variations on similar approaches) for evaluating the impacts of climate change on marine life, biological communities, and ecosystem functions. Although the approaches appeared to be coordinated within communities of modellers, coordination was lacking at the global level. Most, if not all, of the presenters expressed the need to develop these approaches

further, and there appeared to be consensus among participants that an international collaboration would be a good way to do this. A global coordination of teams and collaborators may prove to be a critical vehicle to use the increasingly refined physical and

chemical projections from GCMs and regional models to evaluate impacts of climate change on the world's marine fisheries and ecosystems. The workshop described here may have been a key first step toward such a global collaboration.

Appendix 3.1

List of Participants

Gijón, Spain
May 18, 2008

AUSTRALIA

Christopher J. Brown

CSIRO Marine and Atmospheric Research
GPO Box 1538
Hobart, Tasmania 7001
Australia
Christo.j.brown@gmail.com

Ming Feng

CSIRO Marine and Atmospheric Research
Underwood Avenue
Floreat, Western Australia 6014
Australia
Ming.feng@csiro.au

Alistair J. Hobday

CSIRO Marine and Atmospheric Research
GPO Box 1538
Hobart, Tasmania 7001
Australia
Alistair.Hobday@csiro.au

Elvira S. Poloczanska

CSIRO Marine and Atmospheric Research
GPO Box 1538
Hobart, Tasmania 7001
Australia
Elvira.poloczanska@csiro.au

Bayden Russell

The University of Adelaide
Adelaide, South Australia 5005
Australia
Bayden.Russell@adelaide.edu.au

Evan J. Weller

University of Tasmania/CSIRO Marine and
Atmospheric Research
Private Bag 78
Hobart, Tasmania 7001
Australia
Wellere@utas.edu.au

CANADA

William W.L. Cheung

University of British Columbia
2202 Main Mall
Vancouver, BC, V6T 1Z4
Canada
w.cheung@fisheries.ubc.ca

Michael G. Foreman

Fisheries and Oceans Canada
Institute of Ocean Sciences
P.O. Box 6000
Sidney, BC, V8L 4B2
Canada
Michael.Foreman@dfo-mpo.gc.ca

Thomas A. Okey

University of Victoria/Bamfield Marine Station
P.O. Box 100
Bamfield, BC, V0R 1B0
Canada
Thomas.Okey@gmail.com

DENMARK

Keith Brander

DTU-Aqua
Charlottenlund, DK-2920
Denmark
keith@ices.dk

GREECE

Eugenia Lefkadition

Institute of Marine Biological Resources
Ag. Kosmas, Helliniko
Athens 16777
Greece
tenth@ath.h.cmz.gr

ITALY

Simone Libralato

OGS-Italian National Inst. Oceanography
and Geophysics
Borgo Grotta Gigante
Brisicci 42/c
Sgonico, Trieste 34010
Italy
Slibralato@ogs.trieste.it

JAPAN

Taketo Hasioka

JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama 236-0001
Japan
hashioka@jamstec.go.jp

Kazuaki Tadokoro

Tohoku National Fisheries Research Institute
Fisheries Research Agency
3-27-5 Shinhamachi
Shiogama, Miyagi 985-0001
Japan
den@affrc.go.jp

NEW ZEALAND

Mary E. Livingston

Ministry of Fisheries
101-103 The Terrace
Wellington
P.O. Box 1020
New Zealand
Mary.Livingston@fish.govt.nz

NORWAY

Harold Loeng

Institute of Marine Research
P.O. Box 1870 Nordnes
N-5817 Bergen
Norway
Harold.Loeng@imr.no

REPUBLIC OF KOREA

Sukyung Kang

National Fisheries Research and Development Institute
408-1 Sirang-ri, Gijang-eup, Gijang-gun
Busan 619-905
Republic of Korea
kangsk@nfrdi.go.kr

Jae Bong Lee

National Fisheries Research and Development Institute
408-1 Sirang-ri, Gijang-eup, Gijang-gun
Busan 619-905
Republic of Korea
leejb@nfrdi.go.kr

SPAIN

Antonio Bode

Centro Oceanográfico de A Coruña
Instituto Español de Oceanografía
Apdo. 130, A Coruña, E-15080
Spain
Antonio.bode@co.ieo.es

Ángela M. Caballero-Alfonso

Las Palmas de Gran Canaria University
Las Palmas de Gran Canaria
Las Palmas 35017
Spain
Angela.Caballero.loz@doctorandco.wlpgc.es

THE NETHERLANDS

Adriaan D. Rijnsdorp

Department of Fisheries
Wageningen IMARES
Haringkade 1
P.O. Box 68
Ijmuiden 1970 AB
The Netherlands
Adriaan.Rijnsdorp@wur.nl

U.S.A.

Z. Teresa A'mar

University of Washington
Box 355020
SAFS
Seattle, WA 98195-5020
U.S.A.
zta@u.washington.edu

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

Nicholas A. Bond

NOAA/PMEL, JISAO
7600 Sand Point Way, NE
Seattle, WA 98115-6349
U.S.A.
Nicholas.Bond@noaa.gov

Gordon H. Kruse

University of Alaska Fairbanks
11120 Glacier Highway
Juneau, AK 99801-8677
U.S.A.
Gordon.Kruse@uaf.edu

Alan Haynie

Alaska Fisheries Science Center
NOAA
7600 Sand Point Way NE
Seattle, WA 98115
U.S.A.
Alan.Haynie@noaa.gov

Clarence Pautzke

North Pacific Research Board
1107 W 3rd Avenue, Suite 100
Anchorage, AK 99501
U.S.A.
cpautzke@nprb.org

Jeffrey J. Polovina

Pacific Islands Fisheries Science Center
NMFS, NOAA
2570 Dole Street
Honolulu, HI 96734
U.S.A.
Jeffrey.Polovina@noaa.gov

Jorge L. Sarmiento

Princeton University
300 Forrestal Road, Sayre Hall
Princeton, NJ 08544
U.S.A.
Jls@princeton.edu

Michael J. Schirripa

Northwest Fisheries Science Center
NMFS, NOAA
Hatfield Marine Science Center
2032 SE OSU Drive
Newport, OR 97365
U.S.A.
Michael.Schirripa@noaa.gov

UNITED KINGDOM**Jason Holt**

Proudman Oceanographic Laboratory
Bronlow Street
Liverpool L3 5DA
United Kingdom
jholt@pd.ac.uk

Shelia J.J. Heymans

Scottish Association for Marine Science
Dunstaffnage Marine Laboratory
Dunbeg, Argyll PA371QA
United Kingdom
heilaheyman@sams.ac.uk

Steven Mackinson

Centre for Environment, Fisheries and Aquaculture
Science
Pakefield Road
Lowestoft, Suffolk NR34 0LH
United Kingdom
Steve.Mackinson@cefas.co.uk

Appendix 3.2

Agenda for Workshops 2/3

Linking Global Climate Model Output to (a) Trends in Commercial Species Productivity and (b) Changes in Broader Biological Communities in the World's Oceans

May 18, 2008

- 9:40 **Round Table Discussion of Existing or Planned Research:** Quest-FISH (Holt), FATE (Hollowed), PICES FUTURE (Foreman), NPRB BSIERP (Pautzke), Ministry of Fisheries New Zealand (Livingston), IMBER (TBD)
- 10:40 **Coffee Break**
- 11:00 **Nicholas A. Bond**
A method for using IPCC model simulations to project changes in marine ecosystems
- 11:30 **Mary E. Livingston**
Climate change, oceanic response and possible effects on fish stocks in New Zealand waters
- 11:45 **Jae Bong Lee**
Forecasting climate change impacts on distribution and abundance of jack mackerel around Korean waters
- 12:00 **Sukyung Kang**
Techniques for forecasting climate-induced variation in the distribution and abundance of mackerels in the Northwestern Pacific
- 12:15 **Adriaan Rijnsdorp**
Effects of climate change on sole and plaice: Timing of spawning, length of the growth period and rate of growth
- 12:30 **Z. Teresa A'mar**
The impact on management performance of including indicators of environmental variability in management strategies for the Gulf of Alaska walleye pollock fishery
- 12:45 **Michael J. Schirripa**
Simulation testing two methods of including environmental data into stock assessments
- 13:00 **Alan Haynie**
Climate change and changing fisher behavior in the Bering Sea pollock fishery
- 13:30 **Lunch**
- 14:30 **Introduction to the afternoon and discussion**
- 15:00 **Jorge L. Sarmiento**
Modeling response of ocean biology to climate warming using an empirical approach
- 15:15 **Taketo Hashioka**
Future ecosystem changes projected by a 3-D high-resolution ecosystem model
- 15:30 **William W. L. Cheung**
Dynamic bioclimate envelope model to predict climate-induced changes in distribution of marine fishes and invertebrates
- 15:45 **Alistair J. Hobday**
Informing location choices for ecosystem model development using a vulnerability index
- 16:00 **Coffee Break**
- 16:30 **Simone Libralato**
Towards the integration of biogeochemical and food web models for a comprehensive description of marine ecosystem dynamics
- 16:45 **Steven Mackinson**
Which forcing factors fit? Using ecosystem models to investigate the relative influence of fishing and primary productivity on the dynamics of marine ecosystems
- 17:00 **Sheila J.J. Heymans**
The effects of climate change on the northern Benguela ecosystem
- 17:15 **Discussion of common approaches and workshop synthesis**