PICES Fishery Science Committee Workshop in Gijón

by Thomas A. Okey, Anne B. Hollowed, and Michael J. Schirripa

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 and there was consensus that this group could initiate a coordinated international collaboration to advance research in marine climate impacts. Originally proposed separate 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: (1) to review the activities of existing programs within each nation; (2) to examine evidence for climate impacts on production of commercial fish species and other marine life; (3) to discuss the feasibility of developing medium- to long-term forecasts of climate impacts; (4) to discuss possible responses of commercial fisheries, human communities, and governments to climate-driven changes in marine life; and (5) to 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 examine four components needed to complete the forecasts in a timely and coordinated fashion. These included 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.*, CCCC-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 impact 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 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 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 Ministry of Fisheries New Zealand (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 impact 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 (SST), 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 atmospheric/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 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, a spring bloom 10 days earlier, changes in phytoplankton biomass (*i.e.*, 20% increase in the subarctic region and 25% decrease in the subarctic-subtropical transition region), and a 2° shift in the distribution of sardines.

William W.L. 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 J. 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 impact 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 (UK) 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 (UK) 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 SST 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 in this article may have been a key first step toward such a global collaboration.

Thomas Okey is a Pew Fellow in Marine Conservation with a focus on assessing the impacts of climate change on marine life and ecosystems in the contexts of fisheries and other anthropogenic stressors. He is the Scientist-in-Residence at Bamfield Marine Sciences Centre on Vancouver Island, Canada, and an Adjunct Professor in the School of Environmental Studies at the University of Victoria, Canada. He holds a B.S. in Biology and Environmental Studies from Saint Lawrence University in Canton, New York; a M.S. in Marine Science from Moss Landing Marine Laboratories; and a Ph.D. in Zoology from the University of British Columbia. He is the founder and Science Director of the Conservation Science Institute, which provides conservation science networking and communication.

Anne Hollowed is a Senior Scientist at the NOAA's Alaska Fisheries Science Center, in Seattle, U.S.A. She holds a M.S. in Oceanography from Old Dominion University, and a Ph.D. in Fisheries from the University of Washington. She is an Affiliate Associate Professor at the University of Washington and a Fellow of the Cooperative Institute for Arctic Research at the University of Alaska. Anne has served on panels for U.S. GLOBEC, PICES CCCC, the North Pacific Research Board, and Comparative Analysis of Marine Ecosystem Organization, and is a member of the Scientific and Statistical Committee of the North Pacific Fisheries Management Council.

Michael Schirripa has worked in fisheries science since 1985 for the U.S. Peace Corps, U.S. Forest Service, U.S. Fish & Wildlife, U.S. Parks, and NOAA Fisheries. He earned a B.S. from Michigan State University in fisheries and wildlife and M.S. and Ph.D. degrees in biology from Florida International University. Michael is a member of PICES Fishery Science Committee and is on the Steering Committee of NOAA's Fisheries and the Environment (FATE) Program. Michael recently moved from the NOAA's Northwest Fisheries Science Center in Newport, Oregon, to the NOAA's Southeast Fisheries Science Center in Miami, Florida.