

## The First Year of FUTURE: A Progress Report

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### Where do we stand?

FUTURE is here. After four year's gestation, FUTURE (*Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems*) was born in 2009 and christened as the second integrative science program of PICES. During its life span of ten years, this program is expected to generate a wealth of information and understanding about how ecosystems respond to changes.

Why do we need an integrative science program in PICES? The Strategic Plan of PICES clearly dictates its mission as "*integration of scientific knowledge on the North Pacific Ocean, along with its marginal seas*". To fulfill this mission, PICES requires to synthesize and disseminate knowledge and design appropriate multi-national research programs in response to identified needs. An integrated science program plays a central role in these efforts as it provides the roadmap for scientific activities.

The Climate Change and Carrying Capacity Program (CCCC) was the first integrated scientific program of PICES. CCCC, implemented from 1996–2006, was one of the five regional programs of GLOBEC (Global Ocean Ecosystem Dynamics), thus placing North Pacific science into a global synthesis. CCCC had two scientific questions: (1) how to determine the carrying capacity for higher trophic levels in North Pacific ecosystems and (2) how ocean conditions affect the carrying capacity. Although CCCC was a very successful program and enhanced our understanding of ecosystem processes under climate variability in the North Pacific, its ultimate goal "*to forecast the consequences of climate variability on the ecosystems of the subarctic Pacific*" was not fulfilled.

Through the early discussions in PICES, consensus on requirements for a new science program was identified. First, the scope should be shifted from climate variability (CCCC) to global change (FUTURE). Second, CCCC focused on open oceans, but the next program should be expanded to also include coastal regions. Third, a new capacity of forecasting ecosystem changes should be built in to move beyond simple understanding mechanisms and processes. Fourth, a human dimension should be included that would not only strengthen the research of two-way interactions between nature and humans but also effectively convey this knowledge and predictions to human society.

Based on these requirements, three key questions were developed by PICES scientists and adopted by the Organization as declarations of priorities for FUTURE research activities:

- (1) What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
- (2) How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
- (3) How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

These questions beg us to develop a deeper understanding of ecosystem functioning and to have a forecasting ability built upon this understanding. They also require a new knowledge of how natural ecosystems and human societies interact and change. In addition to the scientific questions, new tasks were identified for making and disseminating useful products for human society. Certainly, this is a new and unknown territory for PICES but also an exciting opportunity for the Organization to grow. Incorporating the requirements of FUTURE science, the Implementation Plan for the program defines two objectives. The first is the scientific understanding and ability to forecast ecosystem changes. The second is to make useful scientific products and to provide these scientific products to society. To achieve this second objective, engagement with potential clients is essential.

In preparation of the FUTURE Implementation Plan, it became clear that the functional structure of the program should be improved. In its implementation, CCCC had its own structure and operated in a somewhat independent way. This resulted in less involvement by the general PICES community than desired. To remedy this, it was agreed that a FUTURE-specific organizational structure would be limited to coordination and direction while the actual work would be done by existing or newly formed expert groups. Thus, three Advisory Panels were born to provide continuing direction, leadership, coordination, and synthesis within PICES toward attaining FUTURE goals: AICE (Anthropogenic Influences on Coastal Ecosystems), COVE (Climate and Oceanographic Variability and Ecosystems), and SOFE (Status, Outlook, Forecast and Engagement). These Advisory Panels are expected to recommend specific activities for consideration by Science Board which serves as the Scientific Steering Committee (SSC) for FUTURE.

As the first year is critical for the success and growth of major programs, PICES made every effort to foster FUTURE. The Advisory Panels needed to develop detailed work plans, and for this purpose several activities took place in 2010:

- At the 2010 inter-session Science Board meeting (April 23–24, Sendai, Japan), one full day was dedicated to FUTURE – it was the first time that Science Board met as the FUTURE SSC. The main objectives of the meeting were to: (1) review the draft work plans for

the Advisory Panels, and (2) clarify the process for revising terms of reference for existing expert groups and approving new expert groups to meet FUTURE goals. At this meeting, Science Board strongly supported the idea of convening a 3-day workshop to advance work plans for FUTURE Advisory Panels and to share ideas on the many common threads they are encountering in moving FUTURE forward.

- The inter-sessional workshop, supported by the Korean government, was held from August 16–18, 2010, in Seoul, Korea. In addition to Advisory Panel members, workshop attendees included representatives from most expert groups associated with these Panels. The goal of the workshop was to expedite the early phase of FUTURE implementation by identifying priority topics and activities for the Advisory Panels for the first triennium (2010–2012) and discussing the potential for existing and new expert groups to address these priorities. The specific outcomes for Science Board review were the work plans for the early phase of FUTURE and recommendations for new expert groups.
- At PICES-2010, the Advisory Panels met concurrently (½ day) and then jointly (½ day) to: (1) review their terms of reference, (2) complete their workplan for the first triennium, and (3) finalize their proposals for new expert groups.

The following are results of what has been reviewed, discussed and planned during and after these events.

### *Surveying PICES priorities*

At our inter-sessional workshop we had considerable discussion about what the priority areas of research should be in support of FUTURE implementation, given the key goal of understanding and forecasting how ecosystems (and the societies that depend on them) respond to natural or anthropogenic stressors. To ensure FUTURE remains relevant to all member countries, a survey was developed and circulated to PICES members *via* Standing Committees. A matrix of major stressors for both coastal and oceanic systems around the North Pacific was developed based on input providing both country and committee perspectives. Although the survey identified regional pressures, it also highlighted a number of high priority stressors across the North Pacific, including climate change, loss of sea ice, hypoxia, organic pollutants, habitat loss, invasive species, harmful algal blooms, and capture fisheries, just to name a few.

### *Existing capacity*

The FUTURE Implementation Plan mandates to achieve the objectives of the program using expert groups. These groups belong to the regular PICES structure, *i.e.*, Governing



Group photo of the inter-sessional FUTURE workshop participants: front row (left to right) – Jongoh Nam (Korea), Hiroaki Saito (Japan), Young-Jae Ro (Korea), Se-Jong Ju (Korea) and Toru Suzuki (Japan); back row – Sinjae Yoo (Science Board Chairman), Suam Kim (Korea), Keyseok Choe (Korea), Masahide Kaeriyama (Japan), Alexander Bychkov (Secretariat), Igor Shevchenko (Russia), Vyacheslav Lobanov (Russia), Phillip Mundy (U.S.A.), Dohoon Kim (Korea), Robin Brown (Canada), Changkyu Lee (Korea), Thomas Therriault (Canada), Steven Bograd (U.S.A.), Jacquelynne King (Canada) and Chul Park (Korea). Absent in the photo: Toyomitsu Horii (Japan), Kyung-Il Chang (Korea), Sukgeun Jung (Korea), Young-Shil Kang (Korea), Hyoung-Chul Shin (Korea). Emanuele Di Lorenzo (U.S.A.), Harold Batchelder (U.S.A.) and Shin-ichi Ito (Japan) participated in discussions by WebEx/Skype.

Council, Science Board, Scientific and Technical Committees. Depending on the scope and lifespan, expert groups are established in the form of Study Groups, Working Groups, Advisory Panels, and Sections. FUTURE Advisory Panels will direct and coordinate the other expert groups' activities in close consultation with Scientific and Technical Committees, and synthesize FUTURE results. Therefore, to address specific scientific questions and make ecosystem-related products, Advisory Panels review the activities of existing expert groups and suggest new expert groups to be established by the relevant Scientific and Technical Committees. At the 2010 meetings, existing expert groups that potentially contribute to FUTURE objectives were reviewed and recommendations were made to adjust their terms of reference to better reflect FUTURE needs. In addition, new expert groups were proposed to fill gaps in implementing high-priority FUTURE activities identified during these events.

#### WG 20 on *Evaluations of Climate Change Projections*

This Working Group, with a lifespan from 2006–2010, was under the Physical Oceanography and Climate Committee (POC). Most of the tasks have been completed, and the final WG 20 report is being written. These tasks included analyzing and evaluating climate change projections for the North Pacific and its marginal seas based on predictions from the latest global and regional models submitted to the Inter-governmental Panel on Climate Change (IPCC) for their 4<sup>th</sup> Assessment Report (AR4). WG 20 also aimed to facilitate the development of higher-resolution regional ocean and coupled atmosphere–ocean models. RCMs (regional circulation models) have been developed or are under development for the California shelf, Washington–Oregon shelf, British Columbia shelf, the Northeast Pacific and the Bering Sea, and the Kuroshio region based on national activities underway. The Working Group made several recommendations including continuation of evaluating IPCC GCM (global circulation models) and RCM results, continuation of analyzing seasonal and decadal projections and variability, establishing live access servers to archive and provide easy access to results from RCMs. Since these are necessary activities for forecasting, they should be incorporated to new expert groups in support of FUTURE science.

#### WG 21 on *Non-indigenous Aquatic Species*

This Working Group is under the Marine Environmental Quality Committee (MEQ). It was approved at the 2005 PICES Annual Meeting, and its terms of reference were revised and lifespan was extended until October 2012 to reflect involvement of WG 21 in a project on “*Development of the prevention systems for harmful organisms' expansion in the Pacific Rim*” supported by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan. The main tasks of this Working Group are to assess the status of non-indigenous aquatic species (NIS) in the North Pacific, to

assemble an inventory of expertise and programs related to NIS in PICES member countries, and to summarize initiatives and best practices on prevention and mitigation measures. Other important tasks are the development of a comprehensive NIS database and a taxonomy initiative which includes Rapid Assessment Surveys to collect initial baseline data and inter-calibrate species collection and identification methods that allow comparisons of invasions within and among nations and can reveal mechanisms and consequences of invasions. WG 21 activities touch on all three key FUTURE research themes, as NIS can represent a significant stressor in aquatic ecosystems, be reflective of ecosystem changes, and humans are a major agent of their introduction and redistribution, often resulting in societal changes. Thus, this Working Group is very closely aligned with AICE but has linkages to both COVE and SOFE.

#### WG 22 on *Iron Supply and its Impact on Biogeochemistry and Ecosystems in the North Pacific Ocean*

The parent committee of this Working Group was the Biological Oceanography Committee (BIO) and its term was 2007–2010. Major tasks for WG 22 were to compile dissolved iron biogeochemistry data in the North Pacific, identify the major sources of transported iron, and identify gaps related to experimental and modeling activities. This Working Group addressed the second key question of FUTURE since iron can regulate ecosystem responses as natural and anthropogenic forcing. The impact of ocean acidification on bioavailability of iron is an open question. The role of iron as a potential regulator of harmful algal blooms in coastal ecosystems was not addressed although it was among the WG 22 terms of reference. Since iron is a modulator of ecosystem productivity and function, and iron availability is likely to change under ocean acidification and anthropogenic activities, a follow-up group is required on some of these issues.

#### WG 23 on *Comparative Ecology of Krill in Coastal and Oceanic Waters in the North Pacific*

This Working Group, with a lifespan from 2008–2011 was established under BIO. The group focuses on the unique ecological characteristics of krill that allow it to populate and dominate in the North Pacific. To understand this question, a comparative analysis of krill biology around the North Pacific rim was adopted. WG 23 also aims to facilitate the inclusion of krill in ecosystem models so as to explore their role in coastal and oceanic food chains, and to address how climate change affects krill distribution and production, which is closely related to the mandate of COVE.

#### WG 24 on *Environmental Interactions of Marine Aquaculture*

This Working Group is under MEQ and the Fishery Science Committee (FIS) and its term is from 2008–2011. The major tasks of this group are to facilitate methods to assess and model the interactions of aquaculture with

surrounding environments. It also aims to assess methods to detect, identify, evaluate and report on infectious disease events and potential interactions between wild and farmed marine animals. It is linked to FUTURE through key questions (2) and (3) as aquaculture is not only an anthropogenic forcing function, but is also influenced by climate. Aquaculture has important social and economic connotations and thus is related to AICE and SOFE.

#### Joint PICES/ICES WG on *Forecasting Climate Change Impacts on Fish and Shellfish*

Within PICES, this Working Group, with a lifespan from 2009–2012, is under FIS and POC. In collaboration with relevant expert groups from both PICES and ICES, its goal is to develop frameworks and methodologies for forecasting the impacts of climate change on marine ecosystems, with particular emphasis on the distribution, abundance and production of commercial fish and shellfish. Since this group aims to explore forecasting techniques, including estimating and communicating uncertainty in forecasts, there is a very important connection to SOFE. It also studies strategies for research and management under climate change scenarios, given the limitations of forecasts. Under the leadership of the group, a very successful science symposium was convened in April 2010 to present, discuss and publish forecasts of climate change impacts on the world's marine ecosystems, with particular emphasis on commercial fish and shellfish resources. While this symposium covered a wide range of forecasting issues from climate variability to human societies, this group needs to focus on specific issues, aligning with other expert groups. The group will continue to be a nucleus of ICES-PICES cooperation, enabling a broader comparison and synthesis beyond the North Pacific.

#### Section on *Carbon and Climate* (CC-S)

This Section was established under POC and BIO in 2005. Its major task is to understand the role of carbon biogeochemistry in a changing ocean. It facilitates ongoing and planned national and international syntheses of carbon cycle research studies in the North Pacific and beyond. CC-S oversaw the publication of the *Guide to Best Practices for Ocean CO<sub>2</sub> Measurements* (PICES Special Publication No. 3, 2007). The Guide is now used worldwide and is considered the definitive reference for the ocean CO<sub>2</sub> system. Another significant undertaking of CC-S is the data synthesis project known as PACIFICA. PACIFICA has collected biogeochemical data (DIC, TA, nutrients, oxygen, and salinity) from more than 200 cruises in the Pacific and has implemented a set of algorithms for crossover analysis that permits the construction of a basin-wide, consistently calibrated dataset. The Section also addresses ocean acidification, de-oxygenation (hypoxia), and productivity: some key issues for FUTURE. CC-S anticipates a shift in focus from carbon biogeochemistry toward biological impacts of ocean acidification, and the

terms of reference were revised in 2008 to reflect this. The Section anticipates particularly strong involvement with COVE, but will likely play an important role in AICE and SOFE as well.

#### Section on *Harmful Algal Blooms* (HAB-S)

The Section was formed in 2003 under the direction of MEQ. The major tasks of HAB-S are to develop monitoring and reporting procedures of harmful algal blooms, build a shared event database, and study mitigation means according to the specific interest of each PICES member country. Building the database is a joint effort with IOC and ICES. The tasks also include enhancing public awareness and education. In 2007, with support from MAFF, the Section initiated a PICES Seafood Safety Project that focuses on preparing and teaching country-specific training courses most required to ensure seafood safety in Pacific countries outside of the PICES region. As harmful algal blooms are a global problem in coastal areas, with significant societal implications, this Section is closely linked to AICE and SOFE. To some extent, it also linked to COVE, as HAB-S is related to all the three scientific questions. The Section will be submitting revised terms of reference at PICES-2011 to ensure that its activities are aligned with FUTURE needs.

#### SG on *Human Dimensions* (SG-HD)

The FUTURE Implementation Plan calls for PICES scientists to make the societal implications of their science more explicit and accessible through long-term engagement and communication activities among scientists, decision makers, stakeholders, and across sectors. This Study Group reviewed the role of social sciences practices applied in decision-making in marine sectors in the PICES member countries, focusing on ecosystem-based fisheries management (EBFM). They found that EBFM challenges are different between the eastern and western sides of the North Pacific, and that approaches are very diverse in the member countries. There is a need to develop indicators for social-ecological systems for which collaborations with social science are required. Spatial scope also was an important issue for identifying stakeholders, defining objectives, conducting research, and implementing policies. SG-HD is expected to produce a draft of its final report by January 2011, and the final report and recommendations by PICES-2011. Human dimensions is one of the new areas where PICES needs to build its capacity, and a new Working Group related to these issues is likely to be proposed at PICES-2011.

#### SG on *Communications* (SG-COM)

This Study Group was established to explore effective ways for better communication both within and outside PICES. Although the Study Group had completed its tasks in 2009, its recommendations are relevant to the engagement issues of SOFE. These include defining

principal audiences for scientific and other products in PICES, exploring various methods of dissemination of scientific publications, and utilizing news media and website communication. SG-COM recognized that FUTURE will face new challenges with communicating *Outlooks* and *Forecasts*, and these require an order of magnitude greater degree of communication sophistication. The Study Group recommended that Science Board consider creating an *ad hoc* committee consisting of professionals from all PICES member countries with experience in science communications (including forecasts and risk/uncertainty). This committee would plan and implement specific PICES communications under a designated PICES structure. In the future, SOFE could provide recommendations on this topic.

### ***New expert groups***

After review and discussion during the 2010 inter-sessional FUTURE workshop and PICES-2010, three new Working Groups were proposed. Among these, the first one was approved by Governing Council in Portland (2010), but the other two were put on hold pending further review and revisions to their proposed terms of reference.

#### ***WG 26 on Jellyfish Blooms around the North Pacific Rim: Causes and Consequences***

This Working Group, with a lifespan from 2011–2014, was established under BIO to study the biology and role of jellyfish in coastal and oceanic marine food webs and to assess the impacts of jellyfish blooms on natural and human systems. This group is closely related to AICE and SOFE, as jellyfish alter the food web and interfere with fisheries and aquaculture activities. The major tasks of the Working Group include understanding the changes in abundance in relation to regional environmental and climate changes, assessing the impacts of jellyfish blooms on marine ecosystems and socio-economies such as fisheries and aquaculture, and evaluating methodologies for predicting blooms and for diminishing their impact on marine and human systems, including bloom forecast modeling and the modification of fishing gears.

#### ***WG on Ecosystem Responses to Multiple Stressors***

The proposal for this Working Group is being revised. If approved, it will be under MEQ and BIO, with a 3-year lifespan. It is anticipated that this group will focus on multiple emerging stressors in North Pacific ecosystems, such as increased temperature, change in iron supply, HAB events, invasive species, hypoxia and eutrophication, and ocean acidification. These multiple stressors can act synergistically to change ecosystem structure, function and dynamics in unexpected ways that differ from single stressor responses. The emerging stressors will vary by region, and critical stressors in PICES' regional ecosystems should be identified. Comparative studies on North Pacific ecosystem responses to multiple stressors will help determine how

ecosystems might change in the future, and also identify ecosystems that are vulnerable to natural and anthropogenic forcing. This Working Group will be able to address issues not resolved by WG 22 (iron chemistry in a low pH ocean, anthropogenic dust flux), WG 23 (hypoxia impact on euphausiids), and WG 21 (non-indigenous marine species) thereby highlighting the need for integrative studies.

#### ***WG on North Pacific Climate Variability and Change***

The proposal for this Working Group is also being revised. If approved, it will be under POC and the Technical Committee on Monitoring (MONITOR). This group will build on the work of WG 20, and its objective is to develop essential mechanistic understandings of North Pacific climate variability and change that can better guide the formulation of process-based hypotheses underlying the links between ecosystem dynamics and climate. The group also aims to develop conceptual models or frameworks of North Pacific climate variability and change that can be readily used by ecosystem scientists to explore hypotheses on the links between ecosystem dynamics and climate. The new Working Group will coordinate, in conjunction with ecosystem scientists, the development and implementation of process-based models to hindcast the variability of available long-term biological time series and explore forecasting.

#### ***FUTURE-related meetings in 2011***

The majority of sessions and workshops to be convened at the 2011 PICES Annual Meeting are relevant to FUTURE. In addition two inter-sessional workshops are specifically planned to advance FUTURE science.

#### ***Indicators of status and change within North Pacific marine ecosystems: A FUTURE workshop***

To answer the key scientific questions of FUTURE, some conceptual and operational issues have to be solved. For example, ecosystem resilience and vulnerability are not operationally defined. Metrics of ecosystem status are required to measure impacts of stressors and monitor change. Ecosystem indicators also could be used to identify systems that are resilient or vulnerable to stressors. In order to ensure that scientists have the ability to detect ecosystem-level changes in a consistent and standardized way, common metrics must be developed. Further, in an attempt to understand the amount of inherent variability in marine ecosystems, these metrics also need to incorporate measures of uncertainty that can be conveyed to end users, including managers and policy makers. The goals of this workshop, to be held April 26–28, 2011, in Honolulu (U.S.A.), will be to identify: (1) the means of determining ecosystem resilience or vulnerability; (2) ecosystem-level indicators of status and change, including but not limited to fisheries-based indicators; (3) methods to characterize uncertainty in these indicators; (4) common ecosystem indicators to be used for regional comparisons by the PICES community.

*International workshop on “Development and application of Regional Climate Models”*

While the global coupled general circulation models (GCMs) may be capable of capturing large-scale mean climate behaviour, they often cannot be directly used for assessing regional climate impacts, mainly due to their coarse spatial scale. Furthermore, they are usually not successful in capturing regionally important physical processes and reproducing higher order statistics and extreme events. Regional climate modeling has been introduced to fill the gap between the GCMs and the growing demand of climate predictions and scenarios on highly-resolved spatio-temporal scales. Various approaches and parameterizations have been adopted in existing regional climate models (RCMs). This 2-day workshop, to be convened October 11–22, 2011, in Incheon (Korea), will provide a platform to discuss various aspects of regional climate modeling such as different approaches, downscaling, parameterizations, and coupling to the GCMs. It will also encompass the coupling of RCMs to ecosystem models.

**Summary**

The key elements of FUTURE are the three overarching scientific questions and engagement with society through the provision of useful scientific products. During the first year of FUTURE, endeavours were made to prepare for advancing some key elements. By reviewing existing and recently disbanded expert groups, gaps were identified and new groups were established or are under development. The Working Group on *Jellyfish Blooms around the North Pacific Rim: Causes and Consequences* will address the three science questions and will contribute to FUTURE ecosystem products. The Working Group on *Ecosystem Responses to Multiple Stressors* will focus on the first two scientific questions at the ecosystem level. With existing expert groups, these new groups will tackle the questions on how natural and anthropogenic pressures are causing changes in oceanic and coastal ecosystems. For outlook and forecast on ecosystem changes, climate–ocean–ecosystem models are needed, and the Working Group on *North Pacific Climate Variability* will take on this issue. The human dimension element is a new territory for PICES to explore. As the Study Group on *Human Dimensions* completes its tasks, it is anticipated that a Working Group to tackle human dimension issues will be formed. In 2011, various FUTURE-related meetings are planned, including two international workshops: a workshop on “*Indicators of status and change within North Pacific marine ecosystems*” in April and a workshop on “*Development and application of Regional Climate Models*” in October.

The new implementation structure of FUTURE overall seems to be working well. Science Board is undertaking

the role of Scientific Steering Committee for the program, and thereby is involving Scientific and Technical Committees in FUTURE work. FUTURE Advisory Panels are acting as coordinators, guiding expert groups to action. This new structure solves the problem of isolating the integrative science program from the other parts of the Organization. However, improvements should be made for better communication between expert groups and FUTURE Advisory Panels. There were concerns that communication is less effective in some cases, and efforts will be made to set efficient two-way communication. Within FUTURE Advisory Panels, sometimes participation is lacking even among PICES member countries. Since member countries have only one, or very rarely, two representatives on each Panel, their active involvement is necessary to ensure that FUTURE is successful in providing products desired by each member country.

Since the role of PICES in the integrative science program is the coordination of international cooperation, national research projects form the basis of FUTURE. During the 2010 inter-sessional workshop, relevant national research projects were briefly reviewed. In all member countries, there seem to be many scientific projects that are potentially related to FUTURE objectives. It was premature to conceive coordinating the directions of national projects at that time, as we are only at an early stage of FUTURE. In the coming years though, it will be necessary to review how these national projects can better be coordinated to enhance the PICES FUTURE program.



Dr. Sinjae Yoo (sjoyoo@kordi.re.kr), as Chairman of Science Board, leads the FUTURE Scientific Steering Committee. Drs. Thomas Therriault (Thomas.Therriault@dfo-mpo.gc.ca) and Hiroaki Saito (hsaito@affrc.go.jp) chair the FUTURE Advisory Panels on Anthropogenic Influences on Coastal Ecosystems (AICE) and Climate and Oceanographic Variability and Ecosystems (COVE), respectively. Mr. Robin Brown (robin.brown@dfo-mpo.gc.ca) leads the Advisory Panel on Status, Outlook, Forecast and Engagement (SOFE). Brief introductions for Sinjae, Tom, Hiroaki and Robin can be found in PICES Press, 2010, Vol. 18 (2).