REPORT OF WORKING GROUP 18 ON MARINE AQUACULTURE

The meeting of the Working Group 18 (WG 18) on *Mariculture in the 21st century – The intersection between ecology, socio-economics and production* was held from 08:30 – 17:00 hours on October 16, 2004. The Co-Chairmen, Ik-Kyo Chung and Carolyn S. Friedman, called the meeting to order and welcomed the participants (*WG 18 Endnote 1*). Welcoming remarks were also made by Drs. Ian Perry (Science Board Chairman) and John E. Stein (MEQ Chairman).

Dr. Perry reminded participants that WG 18 was established at PICES XII (2003) in Seoul (Korea), under the direction of the Fishery Science (FIS) and Marine Environmental Quality (MEQ) Committees. He pointed out that the focus of this group should be on the environmental and ecosystem function, sustainability of production (*e.g.*, carrying capacity of ecosystems), and socioeconomics, rather than on the technology of aquaculture or specific aspects of nutrition of culture species. He also suggested that WG 18 should try and involve other PICES groups to aid in its task.

Dr. Stein emphasized that WG 18 is jointly sponsored by MEQ and FIS – a first time in PICES, and this reflects the broad interest that exists for the topic of mariculture. He noted that MEQ has had several aquaculture sessions at PICES Annual Meetings, and now through the Working Group, would have a focus for more in-depth activities on the scientific issues associated with aquaculture in the PICES region. He strongly recommended that WG 18 should strive to include socioeconomic aspects of mariculture in the North Pacific Region. He also reminded Working Group members that they are also responsible for adding information (reports or presentations) to the MEQ web page on the PICES website. Working Group 18 members should encourage broader involvement from each member country, and think about publishing their results either in the PICES Scientific Report Series or peer-reviewed journals.

The proposed agenda was reviewed and adopted unanimously (*WG 18 Endnote 2*).

National reports on current status and trends in aquaculture (Agenda Item 3)

The terms of reference (*WG 18 Endnote 3*) were reviewed, followed by individual country reports on current status and trends in aquaculture. Summaries of these reports as well as comments and questions from the participants are appended as *WG 18 Endnote 4*.

Discussion and suggestions of WG 18 focus for 2005 and beyond (Agenda Items 4-6)

1. Carrying capacity (K):
   To understand how many organisms may be cultured in a body of water, we need to have a complete understanding of the ecosystem, and learn how ecosystems change over time, thus, allowing alterations to stocking so as not to exceed K.
   a. As technology is changing, we need to be able to incorporate technological impacts of K evaluation
   b. Evaluation of impacts of culture activity on the carrying capacity
      i. Senescence of shellfish grounds due to fecal production
2. Interactions between native and exotic species (local and broader geographic implications):
   a. Evaluate potential of being invasive and competitiveness with native species
   b. Consideration of goal of aquaculture: terminal market *vs.* enhancement/release
      i. Land-based *vs.* water-based farms
3. Disease transfers and management
4. Genetics

5. Ecosystem balance: Assess direct and indirect effects of cultured and wild species on one another – an ecosystem approach
6. Socioeconomics:
   a. Local impacts
   b. Supply-demand-price
      i. Overproduction
      ii. Reduced availability (*e.g.*, due to natural *vs*. anthropogenic influences)
   c. Incorporate lessons learned from agriculture (socioeconomic and otherwise)
   d. How to evaluate values of different coastal activities: scenery, tourism, wild fish-shellfish-plants, aquaculture, and fishing
      i. Integrated coastal zone management.

Other activities for the coming year(s) include:

- To coalesce all presentations from the WG 18 meeting at PICES XIII into a single Power Point presentation for the PICES website;
- To prepare a publication in the PICES Scientific Report series based on the submitted reports on current status and trends in aquaculture in PICES member countries;
- To consider what can be done to attract more scientists from the western Pacific to attend the WG 18 meeting at PICES XIV (October 2005, Vladivostok, Russia);
- To review potential for an inter-sessional meeting of the Working Group prior to the next two PICES Annual Meetings;
- To discuss participation of WG 18 members in the 3rd international symposium on restoration and stock enhancement to be held in 2006, in Seattle, U.S.A. (should PICES be requested to provide travel support for one scientist to attend?);
- To consider more collaboration with ongoing studies or groups such as APEC, ICES, NPAFC, University of Washington's School of Marine Affairs, PICES WG 19 on *Ecosystem-base management science*, etc.

Proposed Topic Session at PICES XIV

Four session topic proposals were discussed:

1. Aquaculture, carrying capacity and ecosystem-based management;
2. Aquaculture, carrying capacity and the human dimension;
3. Aquaculture, carrying capacity, ecosystem-based management and socioeconomics;
4. Current and emerging issues of marine and estuarine aquaculture in the Pacific Region: Carrying capacity, ecosystem function and socioeconomics.

Following consideration of all the proposals, the Working Group recommends that a ½-day Topic Session on "Current and emerging issues of marine and estuarine aquaculture in the Pacific Region: Carrying capacity, ecosystem function and socioeconomics" be convened at PICES XIV (jointly with the Working Group on *Ecosystem-based management science*). This session will bring experts together to identify criteria for suitable indicators and the utilities of predictive models relevant to the impacts of mariculture, to assess the sensitivities of indicators, and to highlight gaps in current knowledge (*WG 18 Endnote 5*). Recommended convenors are Carolyn Friedman (U.S.A.), Glen Jamieson (Canada) and Sergey Pozdnyakov (Russia). Dr. Jian-Guang Fang has been asked to consider if he or one of his colleagues from China would be prepared to serve as a co-convener.

The Working Group plans to convene a 1-day or ½-day Working Group meeting at PICES XIV. To promote cooperation with mariculture experts from Asia, in addition to this meeting, the Working Group recommends holding a separate meeting in Japan or Korea, immediately prior to PICES XIV.

WG 18 Endnote 1

Participation List

Members

Ik-Kyo Chung (Korea, Co-Chairman)
Jian-Guang Fang (China)
Carolyn S. Friedman (U.S.A., Co-Chairman)
Toyomitsu Horii (Japan)
John A. Moores (Canada)
Michael B. Rust (U.S.A.)

Observers

Yukimasa Ishida (FIS Chairman)
Victor Nazarov (Russia)
R. Ian Perry (Science Board Chairman)
John E. Stein (MEQ Chairman)
Ling Tong (China)

WG 18 Endnote 2

WG 18 Meeting Agenda

1. Welcome and introductions
2. Adoption of agenda
3. National reports on current status and trends in aquaculture
4. Summary of presentations and discussion of next steps
5. Consideration of publications and workshops on the current status and trends of aquaculture in marine and estuarine regions that substantively contribute to world aquaculture
6. Relations with other international programs and organizations
7. Other business
8. Adoption of report and recommendations to the Science Board

WG 18 Endnote 3

Terms of Reference for WG 18 on
Mariculture in the 21st century – The intersection between ecology, socio-economics and production

1. To review and report on the current status and projected trends in aquaculture in marine and estuarine regions of PICES that substantively contribute to world aquaculture.
2. To develop an overview of current and emerging issues, with respect to environmental and ecosystem function, sustainability of production (*e.g.*, carrying capacity of ecosystems), and socio-economics.
3. To convene a workshop on "Scientific issues for sustainable aquaculture in the PICES region". A product from the workshop would be recommendations for a PICES Action Plan on scientific issues of mariculture.

WG 18 Endnote 4

National reports on "Current status and trends in aquaculture"

United States (Carolyn S. Friedman and Michael B. Rust)

The United States has a small marine aquaculture industry and thus has more consumers than producers.

Production

More shellfish than finfish production occurs along the west coast of the United States. The number of shellfish farms is on the rise, but increases in salmon production since 1996 are due to increased farm efficiency in lieu of a growing number of farms. Large rises in some new shellfish species are emerging - geoduck and abalone. A small offshore marine finfish culture is developing: Moi in Hawaii and discussion of offshore culture in California (CA) and Washington (WA). Also small land-based marine fish production is observed in Hawaii. In the US, an average 3-4% increase has been observed annually relative to about 12% increase in marine aquaculture globally, and is mostly due to improved technology in the US in lieu of farm expansions. No growth in the capture fishery sector has been observed, so increases in marine products are from aquaculture. Socioeconomic drivers are prominent along the western US - perceived and real competition with wild fisheries and the perception that farming is bad for the environment (a lot of misinformation), and some of this bad reputation is falling into the shellfish arena. There is a growing consumption market for marine products, and the upcoming demographic change projected as baby boomers' age, and more seafood consumption is expected in the next few years. In addition, people are becoming more health-conscious, leading to an increase in per capita fish consumption that results in the net import of seafood noted for the US.

NOAA-NMFS: Uses a science-based risk assessment of aquaculture (common approach to evaluate many issues that is being adopted by the US and EU):

1. Hazard (bad outcome)
   a. Define hazards
2. Risk: Level of risk or probability of the hazard or benefit occurring
   a. Determine risks
3. Benefit: Gain from taking the risk
   a. Define benefits
4. Mitigation strategies: Adjustments to reduce risk or severity of the hazard
   a. Develop mitigation strategies to reduce hazard or risk to acceptable level if not already accepted

This method moves from a qualitative to quantitative assessment of any given activity, including marine aquaculture.

Environmental and ecosystem function

Carrying capacity: We need to consider impacts on the environment and ecosystem. An important component is the carrying capacity (K); as K is approached we may overreach capacity resulting in environmental and ecological impacts.

Native and exotic species: When culturing an exotic or introduced species, we must consider its capacity to become invasive, carry disease and compete with native flora and fauna. When culturing a native species, many concerns also need to be considered, including the genetic diversity of the captive relative to wild populations, and other genetic issues (domestication selection, inbreeding, outbreeding, *etc*), competition and disease.

Genetic issues: Include inbreeding, outbreeding, Ne, selection/domestication which can be controlled to a large extent by breeding programs designed to minimize these hazard and balance Ne with selection/domestication.

Disease: It is important to understand diseases of both wild and cultured animals, and to apply established methods to avoid disease introduction. Such methods will reduce the risk of moving infected stocks, or reduce selection of sites where disease agents are prevalent in wild stocks but will not entirely preclude the potential for disease outbreaks. Parasites and diseases are natural components of the ecosystem and function to modulate population dynamics; in crowded culture systems disease expression is often enhanced relative to its expression in wild conspecifics.

Public awareness and stewardship: In the United States, non-governmental Organizations (or NGOs) and public education are key to public acceptance of cultured aquatic and marine products. The US desires safe, high quality seafood at a low price that is produced by an environmentally-safe method.

Comments/questions

1. PICES is evaluating the status of the North Pacific ecosystems, and information from this work may be applicable to WG 18's goals.
2. We need to think about the carrying capacity of the entire ecosystem that we are assessing for aquaculture. Some work is being done along Prince Edward Island, (Canada) regarding mussel culture and the ability to influence phytoplankton levels, but we need data on ecosystem impacts.
3. We need to assess how to integrate science and social aspects including risk aversion (*e.g.*, any risk is too much).
4. Perhaps comparing impacts of aquaculture to other accepted marine resource utilization, such as fishing or ecotourism, will allow the public to make decisions based on relative impacts.
5. We should consider studies by charitable foundations (*e.g.*, PEW) and the impact of such funded studies on public perceptions.
6. Aquaculture practices and scales vary between sites, regions and countries: The development of Best Management Practices (BMPs) may aid in minimizing impacts.
7. Some felt that the amount of fear over aquaculture was disproportion to its scale.

Canada (John Moores and Susan Bower)

Canadian issues are similar to that of the US. A lot of different aquaculture occurs on the west and east coasts, and inland waters with many companies established in multiple regions.

Production

Western Canada has ~27,000 km of coastline, and a lot of this shoreline is protected and may be used for aquaculture, with most concentrated around population centers but still away from cities in more pristine areas. Due to the pristine state of these sites, conflict with preservationists is an issue. Also often salmon farms and shellfish companies may compete for the same sites. Baynes Sound and Cortes Island are shellfish production oriented, and Broughton Sound contains more salmon culture operations. Production is estimated at 90,000 mt (90 Kmt) annually with Atlantic salmon at 73 Kmt, Chinook at ~10 Kmt and oysters at 7.2 Kmt. Expected production: now is 3900 ha and there is a plan to expand 5 times with new species under development. Canadian aquaculture has been increasing ~10% annually, but recently has reached a plateau due to regulations and other impacts. Culture sites are subject to Canadian Environmental Assessment Act approval, and both Federal and Provincial governing of aquaculture. Canada is looking to implement an Integrated Management Approach: All stakeholders have a right to a voice (Oceans Act).

Environmental and ecosystem function

Carrying capacity: Insufficient information exists leading to a precautionary approach. There is a need to establish standards (Canada is developing codes of practice to minimize risk and build on existing knowledge; it is also hard to identify any impacts solely due to aquaculture) and to look at alternate techniques.

Native and exotic species: Introduced species include Atlantic salmon, Pacific oysters, and

Manila clams. Concern exists about displacement of native species, escapement, genetics and disease as well as displacement of other industries such as fisheries. Canada is looking to develop sablefish, Pacific halibut, geoduck, abalone and algae farms. A key question entails: When is a species domesticated? As there are likely to be large differences in cultured and wild congeners due to selection within a farm, it may be important to identify criteria for domestication.

Sustainability of production: Industry priorities: Fish health, breeding programs, alternate feeds, species interactions. The government is interested in environmental interactions and may not share same interests as scientists.

Genetics: Broodstock development, sources of seed are of key concern in the genetic management of farms.

Diseases: IHN, *Kudoa*, sea lice, mikrocytosis occur in Canada. Most are naturally occurring (see DFO web site). British Columbia has a Health Management Plan (only use of certified fish is allowed, which will reduce but not preclude the risk of disease).

Feed supply: A limit exists to the amount of forage fish available and there is concern over the culture of carnivores that rely on wild fish for protein. Feed is estimated to represent ~33% of culture costs; thus Canada is looking for alternative protein sources. There is interest in minimizing nutrient loading (P in freshwater and N is seawater) and trying to minimize associated impacts.

Socioeconomics: Annual revenue from mariculture is estimated at $300 M, with 576 licensed sites, 2000 direct on-farm jobs and, if related jobs are included, from 6000 or up to 14000 jobs are associated with marine aquaculture. This industry also serves as the economic and ceremonial base for rural and First Nation communities (hard to quantify this latter benefit of aquaculture).

Restoration of stocks: Not considered true aquaculture as seeks to maintain characteristics of wild stocks. There is a feeling that if we put aquaculture and restoration together (*e.g.*, restoration aquaculture) it may lead to problems. Many programs exist to enhance stocks (Salmon Enhancement Program). Programs to preserve endangered stocks also exist: abalone in British Columbia and salmon in Bay of Fundy on the east coast.

Public awareness: This aspect is considered very important. In general, throughout Canada, a positive response to aquaculture exists. However, there is also controversy over aquaculture, especially along the west coast of the country. We need to increase knowledge base and communicate effectively.

<u>Comments/questions</u>

1. Currently in the US, state hatcheries need NEPA approval.
2. There are challenges due to differing mandates of Canadian governing bodies: federal and provincial.
3. Where aquaculture occurs, it is conducted at high densities with site-specific problems. This is still a new industry and needs to move up the learning curve. There is a need to look at political concerns and put these into perspective, perhaps by including lessons learned from other countries.
4. Using an ecosystem approach needs improvements; it is hard to evaluate impacts if ecosystem characterization is lacking.
5. It is time to look at compromises between production and environmental assessments.
6. Dr. Ishida wanted to know what issues exist for the three main species cultured along the eastern Pacific: Salmon, oysters and clams. This was discussed later in the meeting.

Korea (Ik-Kyo Chung)

<u>Production</u>

Production fluctuates in Korea, in part, in conjunction with economics.

Total aquaculture: Shellfish and seaweed cultures are decreasing but fish culture is increasing; seaweed culture is the largest component of the industry and its contribution fluctuates annually. Marine aquaculture based on value is rising, with fish in the lead over shellfish and seaweed, both of which are declining. Shellfish: oysters represent 80% of production; seaweed: *Undaria* and *Porphyra* are the most frequently cultured (90% combined). Although shellfish aquaculture is declining, more people are engaged in this culture industry, while fish culture is stable regarding the number of farms and sizes of culture sites. Most species are cultured in the south: eastern regions focus on fish and western regions focus on shellfish and seaweed.

Fish products: Live raw fish predominate, and recently Korea has been trying to expand markets to include fresh types of processed fish. Seaweed prices reflect the amount of production, and the industry needs to pay attention to this.

Luxury versus subsistence: Luxury items are the first stage of any operation and may become subsistence as the industry grows. Fish and abalone are highly valued and take priority. Most production is consumed locally in Korea.

<u>Environmental and ecosystem function</u>

Carrying capacity: Estimation of carrying capacity is necessary to maintain sustainable production and to protect the environment from impacts of culture activities. Research is on-going and uses the ecosystem model EUTROPII based on physical and eutrophication processes in the coastal bays. This model is used to incorporate the size of production to calculate the amount of species X that can be produced in that area; production-oriented, not whole bay ecosystem.

Genetics: The number of exotic species cultured is small and these species are the in early stages of introduction. Korea is doing genetic assessments (and has information) on several native cultured species as compared with wild conspecifics.

Wild and native species: No competition issues between wild and cultured organisms have been identified in Korea.

Disease: This issue is considered important, and laboratories are working on diagnostic methods, but this research is in its early stages.

Sustainability of production: Culture to enhance production in an environmentally sound and economically successful manner. Strict regulations for use of the coastal environment is leading to research on recirculating systems, integrated polyculture, and off shore systems.

Socioeconomics: Fishery household income has declined, while cost of marine products is on the rise, but price of some cultured species has declined (*i.e*., oysters, bastard and laver, often due to over production as occurred in 2002).

Restoration aquaculture: This has been practiced for 25 years. 12 National Fisheries Hatchery laboratories are involved, and 375 M individuals have been released. Korea has produced artificial reefs and released seed/spat. Now higher numbers of individuals and more species are being released. Salmon: 260 M smolts over 35 yrs and returns of 1-1.5% in the 1990s. Now due to the success of increases from released smolts, salmon season has been expanded and related income has risen:

- about 56 species are under mass production;
- 50 species are in the pilot scale production;
- 30 species are in the initial stages of development;
- researchers are considering genetic and disease issues.

Methods: Conflicts exist regarding how to evaluate the use of artificial reefs: Some seem to work, some do not. Researchers are thinking about genetic effects and methods to reduce genetics impacts and rates of releasing animals.

Public awareness: Ministry of Marine Affairs and Fisheries has the following three basic objectives: (1) promoting the vitality of our territorial waters; (2) development of a knowledge-based marine industry; and (3) sustainable development of marine resources. To attain its vision and objectives efficiently, Ocean Korea 21 (OK21) has 7 specific goals consisting of 100 special projects. As part of the policy initiatives for sustainable development, which is a new paradigm of the 21st century, a comprehensive program for marine environment conservation has been set up for implementation. There are plans to make some practices compulsory.

Japan (Toyomitsu Horii)

Production

A 33% decline in capture fisheries has been documented between 1991 and 2001, in both volume and value, while aquaculture has been stable in volume:

- yellowtail production and price has remained stable for 20 years;
- red sea bream increased in volume but reduced in price due to imports;
- the volume of flounder has increased but is stable now, and price is decreasing;
- the volume of ocellate puffer is on the rise but price is flat or has decreased slightly; this species is on the rise as culture methods improve;
- scallop production increased to a stable level since 1990, and currently price is reduced due to oversupply;
- stable price and volume produced are noted for oysters; tango are stable also;
- the sea mustard industry has had a stable price despite reduced volume produced; laver is also stable.

Most products are consumed locally but some are exported. Volumes and prices generally are stable and some luxury species (*e.g.* puffer) are on the rise.

Environmental and ecosystem function

Current and emerging issues: These include environmental degradation, damage to fish due to pollution (*i.e.*, red tides), and disease. Not much concern is expressed over genetics as local species are cultured.

Sustainability of production: In 1999, the law was established to ensure sustainable aquaculture production. Specific disease lists were developed for the three primary cultured organisms, including shrimp, and two fish species.

Socioeconomics: Declines in some fish species have resulted in socioeconomic impacts.

Restoration aquaculture/stock enhancement:

- salmon releases have resulted in increases in the number fished;
- red sea bream has a stable release/catch program;
- the number of flounder seed released have resulted in a stable catch;
- increases in abalone seed not been able to reverse a trend of decreased catch (over-fishing and environmental change are thought to contribute to this trend);
- the scallop catch and release programs appear balanced;
- remarkable results have been noted for salmon and scallop programs, and Japanese researchers are evaluating the results of stock enhancement programs for other species.

Concerns: Disease is the top concern over genetics or carrying capacity.

Comments

1. Has the optimal size of planting been determined for each species? Dr. Horii indicated that a balance between size and

cost is the method of determining this value for each species.

2. The goal of the enhancement programs was asked, and Dr. Horii responded that some programs are designed to replenish stocks (*e.g.*, aid in returning to self-sustaining populations), while others are perpetual release programs.

China (Jian-Guang Fang)

<u>Production</u>

Since the 1970s, mariculture has been on the rise and has made substantial contributions to seafood production. Most production is based on shellfish (80% of production); seaweed is next in volume. Fish cultured include: Japanese sea bass, yellow croaker, red drum, sea bream and flat fish. Shrimp cultured include: *L. vannamei* and *L. chinensis*, and the culture industry is on the rise after decimation due to disease. Crabs are also cultured.

The most important species include: oysters, clams, scallops, razor clams, mussels and abalone in descending order. Abalone: *H. disucs hannai* in the north and *H. diversicolor* in the south. China is the largest producer globally and is still expanding production. The vast areas and densities in production are leading to environmental concerns.

Cage culture makes up 50% of total production of fish. Varying farm methods are used from extensive to intensive.

<u>Environmental and ecosystem function</u>

Carrying capacity: In order to assess carrying capacity (K), primary production and POM is measured to estimate filter feeding rates, zooplantkton consumption, and to project the amount aquaculture that can be sustained in a given area. Based on the models used some species were cultured in densities that exceeded K by 20-100%. As an example, in Sungo Bay, algae and smaller sized scallops exceeded K, while medium-sized scallops were balanced with primary production and larger scallops were below their K. Now Chinese researchers are trying to reduce production densities via polyculture (*i.e.*, fish and *Laminaria*, and also integrate seaweed with shellfish on long lines, integrated or adjacent block methods, as well as sea cucumber and mussels co-culture). Polyculture has increased yields: *e.g.* polycultured *Laminaria* increased in yield 45% over that species in monoculture.

Impacts on the environment: In Sungo Bay, kelp, oyster and scallops are the main species cultured and are reared in high densities. High harvest levels reduce large volumes of N and P in the bay. When combined with the filtering capability of filter feeders, reduced nutrient loads have been observed (bivalves may filter 38% of Sungo Bay water per day). In addition, chlorophyll *a* levels have declined.

The impact of seaweeds on other species depends on nutrients available in the bay. Impacts on benthos have been noted for those in suspension culture: 2 times more feces produced for each bivalve harvested (*i.e.*, 2 MT feces for 1 MT harvest) and, by calculations, could result in 10 cm of fecal sediments; but currents carry away a large amount of fecal material. From 1993 to 2004, changes in the benthic community with reduced biodiversity from over 200 to 30 species have been documented. Suspended culture has also reduced sea grasses. Re-suspension of sediments result in bivalve losses and lead to algae blooms, reduced light penetration and reduced sea grasses and benthic algae.

Researchers have established models to examine these impacts and to evaluate impacts on culture, and the environment and human health. There is a need to establish management practices.

Russia (Victor Nazarov)

Production

Current status: Northern Russia has a small population and no aquaculture (Koriak region has only 1 farm); Kamchatka: release Pacific salmon from 10 farms (pink, chum, less coho, and even less chinook); Magadan: 4-5 anadromous ponds; next district: more maricultre but less than 20 farms for releases (>1 billion pink and chum released); the next region to the south has 5 farms for salmon release (200,000+ smolts released); the next district has mariculture development programs to produce 1000 farms for scallops, mussels and sea cucumbers; the southernmost region has 3 kinds of aquaculture: freshwater, anadromous and sturgeon (>50 tonnes), Pacific salmon releasing ponds for chum (<50 million fingerlings); the southernmost area is just beginning the practice of aquaculture (in 2000, began mariculture development for scallop, seaweed, mussels, sea cucumber and oysters). Most farms here are quite small because of small demand. Products are for domestic consumption.

Problems of disease, sustainability are not known as Russia only has a small industry, and does not expect industry expansion in coming years.

Most farms are governmentally owned and only a few, located in one territory, are private.

WG 18 Endnote 5

Proposal for a ½-day MEQ/FIS Topic Session at PICES XIV on "Current and emerging issues of marine and estuarine aquaculture in the Pacific Region: Carrying capacity, ecosystem function, and socioeconomics"

It is well recognized that for successful and long-term utilization of waters for aquaculture and other uses, we must consider the allocation of resources and trophic structure of the system. Ecosystem-based management of resources requires ways to monitor current conditions and predict future states, particularly in response to known human activities that impact the marine environment. Mariculture is an important expanding industry in all PICES countries, and this session will consider mariculture as a case study on how the ecosystem impacts of a particular human activity can be managed. Indicators and predictive models are being used to evaluate and hypothesize the responses of an ecosystem to environmental impact and resulting management actions. This session will bring experts together to identify criteria for suitable indicators and the utilities of predictive models relevant to the impacts of mariculture, to assess the sensitivities of indicators, and to highlight gaps in current knowledge.

Recommended co-conveners: Jian-Guang Fang (China), Carolyn Friedman (U.S.A.), Glen Jamieson (Canada) and Sergey Pozdnyakov (Russia).