REPORT OF STUDY GROUP ON MARINE AQUACULTURE AND RANCHING IN THE PICES REGION

Terms of reference

At PICES XV (October 2006, Yokohama, Japan), a Study Group on *Marine Aquaculture and Ranching in the PICES Region* (hereafter SG-MAR) was established under the direction of Science Board (Decision 06/A/6), with terms of reference as follows:

1. To review and access why WG 18 had limited success in achieving its terms of reference;
2. To determine the highest priority marine aquaculture and/or ocean ranching science needs (< 10) for the next 5–10 years in each PICES member country;
3. To develop recommendations for joint activities in marine aquaculture and/or ocean ranching using the PICES Action Plan format;
4. To provide its draft report by September 2007 and be prepared to discuss and finalize the report at PICES XVI (October 2007, Victoria, Canada).

The approved membership of the Study Group is included in *SG-MAR Endnote 1*.

Executive Summary

The Study Group worked over the past 8 months by correspondence to address its four terms of reference. To deal with the first item, an e-mail was sent to former members of the Working Group on *Mariculture in the 21st Century – The Intersection between Ecology, Socio-economics and Production* (WG 18 was approved at PICES XII in October 2003 and disbanded at PICES XV in October 2006 due to inadequate progress in achieving its tasks), but very few responses were received (*SG-MAR Endnote 2*). This reflects WG 18 itself which suffered from lack of participation. Numerous factors may have led to the low participation and they are presented in the report below. Low participation is a sign that the work or work products of the Working Group are not relevant to the members. Even if these products are a high priority for PICES leadership, they first and foremost have to be meaningful to the Working Group members themselves.

To determine the highest priority marine aquaculture and ocean ranching science needs for the next 10 years, each country was asked to develop a list independently, and send it to SG-MAR Chairman, Dr. Michael Rust, for consolidation (*SG-MAR Endnote 3*). These lists (*SG-MAR Endnote 4*) were combined into like items and then examined to see if any higher order grouping was possible. Priorities were divided into two groups, depending on their relation to environmental impacts of commercial aquaculture or ranching or to advancements in technology. Priorities were developed based on the number of countries listing a given topic. The three top priorities (cited by 6, or 5 of 6 countries) were related to:

- development of aquaculture technology and systems;
- management of stocking and supplemented fisheries; and
- estimation of the carrying capacity of commercial aquaculture activities.

Recommendations

Based on these priorities, SG-MAR recommends the formation of up to two PICES Working Groups to foster joint activities on:

1. *Environmental Risk Assessment and Interactions of Marine Aquaculture*;
2. *Technology and Management for Aquaculture.*

Mission, Strategy and Action Plans for each Working Group are presented in *SG-MAR Endnotes 5 and 6.* Potential sponsoring committees could be: MEQ for #1 and FIS for #2. Alternatively, a new Aquaculture Committee

could sponsor both Working Groups, or they could be supported jointly by MEQ and FIS.

SG-MAR TOR #1: To review and access why WG 18 had limited success in achieving its terms of reference

The Working Group on "*Mariculture in the 21st Century – The Intersection between Ecology, Socio-economics and Production*" (WG 18) was approved at PICES XII (October 2003, Seoul, Korea), with the following terms of reference:

1. 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. 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. 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 first met at the PICES XIII in Honolulu, U.S.A., then again at PICES XIV in Vladivostok, Russia and PICES XV in Yokohama, Japan. To its credit, WG 18 had accomplishments. Three scientific sessions were held in Honolulu, Vladivostok and Yokohama. Reports from each country were produced and published by PICES. Had the Working Group continued, it might have been possible to have overviews of current and emerging issues developed (TOR #2), based on the three scientific sessions held. These products fell largely to SG-MAR by producing this report.

To address the first SG-MAR term of reference, an e-mail (*SG-MAR Endnote 2*) was sent to all the members of former WG 18 to solicit their input on the reasons why the Working Group was able to only partially fulfill its terms of reference. The following is a synthesis of the few responses that were received.

While it is difficult to say why WG 18 was not fully successful, several possibilities exist and were pointed out by its members. These include: (1) the development of the terms of reference; (2) the expertise of the members; (3) the lack of pre-existing personnel relationships among the group; and (4) the isolated position of aquaculture within the larger framework of PICES.

Most, if not all the scientists in WG 18 were new to PICES and were invited at the recommend-dation of PICES members who did not have a background in aquaculture. The terms of reference were also developed by scientists who were not active in aquaculture, and the usefulness of some of the terms was questionable. For example, FAO and various national agencies typically have organizations to track status and trends by country and region (TOR #1) so why would PICES want to duplicate that?

There was an initial social inertia as scientists got to know each other and the PICES system. This was made more difficult by the diversity of specializations among the group and the isolated nature of aquaculture within the larger PICES framework. Much of the rest of PICES is of low relevance to aquaculture scientists, and aquaculture is of low relevance to other PICES expert groups. This combination provided little incentive for members to attend the Annual Meetings. Since most scientists have limited travel budgets they were forced to choose between attending PICES Annual Meetings or international aquaculture meetings.

In the end, the combination of these factors, and possibly others, resulted in low participation in the Working Group. Low participation is a sign that the work or work products of the group are not relevant to the members. Even if these products are a high priority for PICES leadership, they first and foremost have to be meaningful to the Working Group members themselves.

SG-MAR TOR #2: High priority marine aquaculture science needs (5–10 years)

For this term of reference, each country was asked (*SG-MAR Endnote 3*) to provide the top ten aquaculture priorities over the next 5–10 years. Responses were tallied and grouped where similar priorities were identified by more than one country. They are presented below in order of the number of countries expressing them as a priority. The unedited responses are provided in *SG-MAR Endnote 4*. Identified priority research areas include:

Development of aquaculture technology and systems (all Contracting Parties):
- Development of efficient, environmentally-friendly, and industry-diversifying culture technologies for fish, shellfish, and algal species and the polyculture of these groups;
- Improvement of technology for open-ocean and multi-tropic level aquaculture;
- Technology development should be inclusive of that needed to increase production and/or decrease the environmental footprint.

Stocking, population dynamics and management of supplemented stocks (Canada, China, Japan, Korea, U.S.A.):
- Evaluation and improvement of stocking;
- Assessment of the risks (genetic, harvest, ecological and disease) from interaction between cultured (commercial escapes), enhanced (hatchery releases) and wild fish;
- Development of technology to minimize wild/cultured fish interactions;
- Assessment of efficacy of programs for stock rebuilding and management;
- Evaluation of the effect of stocking on resource fluctuation and improvement of stocking technology;
- Application of fisheries management and population dynamics models to marine ranching activities.

Estimation of carrying capacity for aquaculture activities (Canada, China, Korea, Russia, U.S.A.):
- Development of biological and oceanographic models;
- Use of models to determine best zones for aquaculture;
- Collection of lab and field data to allow prediction of ecological effects (near and far-field) of aquaculture;
- Determination of carrying capacity of aquaculture areas and for released species;
- Monitoring and prediction of the impacts of global climate change on aquaculture industries;
- Development of methods to assess risk to ecosystem and industry.

Disease treatment development (Canada, China, Russia, U.S.A.):
- Investigation of disease transmission (bi-directional) between wild and cultured stocks;
- Development of aquaculture vaccines and other effective treatments.

Genetic management of aquaculture and released stocks (Canada, China, Japan, U.S.A.):
- Use of biotechnology, genomics, and genetics to improve commercially important traits (*e.g.*, growth, disease resistance and reproduction) and the assessment of improvements;
- Development of methods to maintain wild type genetic diversity in stocking programs.

Feeds development (Canada, Japan, U.S.A.):
- Development of environmentally friendly feeds and cost-effective feeders for marine organisms.

Assessment of the impact of aquaculture on species at risk (Canada)

Investigation of the potential for fishermen to self-regulate fisheries resources management (Korea):
- If they control their capture amount, size and periods for resources management by themselves, the marine ranching program may be more effective (Korea).

Development of alternative income sources for fishermen to reduce capture (Korea):
- When they have another income source tied to the ocean, they will make an effort to sustain marine resources. Therefore, we should investigate developing alternative

income sources focused on ocean tourism and leisure. Consideration of infrastructure needs for developing tourist areas should also be considered.

These various priorities for aquaculture research can also be grouped by general topic as presented in Table 1. The priorities clearly fall into three over-arching topics: (1) Technology improvement, (2) Environmental carrying capacity, and (3) Social and economic issues. In all three topics, there could also be a distinction between aquaculture used for commercial production and aquaculture used for resource management (enhancement or ranching). The priorities identified as socio-economic issues are not unique to aquaculture, but also include the capture fisheries sector.

Table 1 Priority aquaculture research areas and numbers of Member Countries interested

Topic Group	Specific Topic	Nos.
Technology development	Development of husbandry techniques	6
	Genetic management (breeding/improvement)	4
	Disease treatments	4
	Feeds development	3
Environmental issues Risk, Monitoring, Modeling and Management of released organisms and Risk, Monitoring, Modeling and Management of commercial aquaculture systems	Evaluation of stocking	5
	Carrying capacity	5
	Genetic management (maintaining wild genotypes)	4
	Population dynamics and management of stocked populations	5
	Impacts on highly vulnerable resources	1
	Provision of self-regulation for fisheries resources management	1
Socio-economic issues	Provision of self-regulation for fisheries resources management	1
	Development of alternative income sources for fishermen	1

SG-MAR TOR #3: To develop recommendations for joint activities in marine aquaculture and/or ocean ranching using the PICES Action Plan format

ICES, the older sister organization to PICES, has a long history of Working Groups dealing with aquaculture. Currently, they have groups focused on technology (marine fish, shellfish, genetics and animal welfare) and environmental interactions (environmental interactions of mariculture). Groups that are easily identified with aquaculture make up about 6 of the ~100 groups working under ICES. Several more likely have aspects of their work related to aquaculture (*e.g.*, salmon or basic physiology). Aquaculture-related groups within ICES seem to be focused on themes that would appeal to specialists. Given that the PICES region has a large and more diverse aquaculture sector than the Atlantic, it would appear that an effort of a similar or greater magnitude would be desirable.

It is clear from the diversity of topics that are associated with aquaculture that there is a large degree of specialization. A symposium could easily address any of the 31 topics listed in *SG-MAR Endnote 4*. Given the priorities of PICES member countries, there is a pressing need to: (1) develop, improve and evaluate aquaculture technology, and (2) assess impacts and limits to the environment. The latter was often expressed as determining the carrying capacity for a given aquaculture activity (whether for release or production) and identifying the environmental risks associated with aquaculture. In many ways these two aspects of aquaculture go hand in hand because,

as technology improves, the environmental footprint of the industry will likely change. In most cases, improvements in technology should lead to reductions in environmental impacts. For example, improved feeds will pollute less and utilize fewer marine resources. Improved vaccines will reduce disease in cultured fish and the risk of transfer it to wild stocks. Improved cage designs will reduce the risk of escapes, and improved hatcheries will reduce the reliance on catching juveniles in the wild. This has been the case in the salmon net-pen industry, for example.

We suggest that PICES groups working on aquaculture technology focus on technology and methods that provide both an economic and environmental benefit. This should aid in their adoption by the end-user groups and reduce the footprint of aquaculture activities.

Several topics are associated with a need to understand, assess, and manage risk in various areas of aquaculture. Risk assessments may be useful as a common way to approach a wide array of issues related to aquaculture and may help to guide and set priorities for the development of improved aquaculture technologies and practices. This topic is timely as PICES was asked to join with the ICES Working Group on *Environmental Interactions of Mariculture* (WGEIM) to convene a joint meeting from April 14–18, 2008, in Victoria, Canada. Reports produced over the last three years by WGEIM are impressive because it has developed and applied environmental risk assessment to marine aquaculture. The Working Group's reports are available from the ICES website. While some SG-MAR members felt that the risk assessment approach may be too difficult and costly to apply in the PICES region, the Study Group recommends that PICES accept the opportunity for a joint workshop, use it to train PICES scientists in risk assessment, and launch a Working Group in this area (*Environmental Risk Assessment and Interactions of Marine Aquaculture* – ERAIMA). A proposal along these lines is described in greater detail in *SG-MAR Endnote 5*. The application of risk assessment to issues identified in the PICES region could not only be a unifying approach for PICES groups focused on aquaculture but also with ICES and other international efforts.

Given the priorities of PICES member countries, SG-MAR also recommends forming a PICES Working Group to focus on *Technology and Management for Aquaculture* (TMA). A more complete description of the proposal appears in *SG-MAR Endnote 6.*

We should wait until after the 2008 ICES/PICES workshop before adopting final terms of reference and action plans for either of these groups. There would be an emphasis on the development of technology and an assessment of the impacts of those technologies on the environment by both groups, with a goal of encouraging technologies that have both an economic and environmental benefit.

To avoid the difficulties faced by WG 18, the Study Group recommends that the terms of reference for these new groups be finalized by the members themselves, using the draft terms provided in *SG-MAR Endnotes 5* and *6*, and this report as a guide. Opportunities may exist at PICES XVII (Dalian, China, October 2008), at the World Aquaculture Society Meeting (Busan, Korea, February 2008) or at the World Fisheries Congress (Yokohama, Japan, October 2008) to attract aquaculture scientists to these groups.

Although a recommendation for reporting relationships for these proposed Working Groups is beyond the scope of the terms of reference for SG-MAR, it is included for consideration. These Working Groups could report to the existing PICES Committees, with ERAIMA falling under MEQ, and TMA under FIS. Alternatively, there may be some advantage of forming a new Committee focused solely on aquaculture, or they could have joint support by MEQ and FIS.

SG-MAR Endnote 1

SG-MAR membership

Dmitry Galanin (Russia)
Galina S. Gavrilova (Russia)
Toyomitsu Horii (Japan)
Jie Kong (China)
Hyun Jeong Lim (Korea)
Michael B. Rust (U.S.A., Chairman)
Terri Sutherland (Canada)

SG-MAR Endnote 2

E-mail to members of Working Group 18 on
Mariculture in the 21st Century – The Intersection between Ecology, Socio-economics and Production

Dear PICES WG 18 member,

I am writing you for two reasons. First to provide you with a copy of the final reports for the WG 18 meeting (with recommendations) and the Topic Session on "*Aquaculture and sustainable management of the marine ecosystems*" held at PICES XV in Yokohama, Japan. These are both attached. I am happy to discuss either of these two documents if you have any questions.

Second reason is to ask for your thoughts on how the Working Group could have been more productive. As most of you know, WG 18 was dissolved by the Governing Council at their meeting in Yokohama largely due to a perception on the part of MEQ that the group was not meeting its terms of reference. A Study Group was formed: (1) to determine why the terms were not met, and (2) to recommend what PICES role in aquaculture should be in the future.

As the last activity of WG 18, I would appreciate hearing your thoughts on these two items to provide guidance to this new Study Group. It will help PICES become a more effective Organization. I will keep all responses anonymous and will just provide a general result with suggestions to the Study Group. The Study Group is formed for only one year and will deliver its report this fall at the Annual Meeting in Victoria, Canada.

Thank you for your time and help with this matter. It has been a pleasure working on WG 18 with you all. I hope we will have a chance to work together again.

Mike

Michael B. Rust, Ph.D.
Northwest Fisheries Science Center
2725 Montlake Blvd E
Seattle, WA 98112 USA

SG-MAR Endnote 3

E-mail to members of Study Group on *Marine Aquaculture and Ranching in the PICES Region*

Dear Marine Aquaculture Study Group,

First of all, let me welcome you all to the PICES Study Group on Marine Aquaculture. I look forward to our dialogue over the next 8 months. As a Study Group we have limited time to produce a document and presentation addressing our terms of reference. According to the PICES Rules of Procedure (Rule 15):

"A Study Group is established by the Council or an Executive Committee, with the approval of the Council, for a period not normally exceeding one year, with specific terms of reference, to consider any scientific, policy, advisory and/or financial issue of interest to the Organization and to provide recommendations thereon. A Study Group:

(i) shall normally consist of members appointed by the Contracting Parties, and by the Council;

(ii) shall establish one Chairman according to Rule 17;
(iii) shall be disbanded after submitting their final report and recommendations."

We have been asked by PICES to provide some guidance on what PICES' role should be in aquaculture science. Specifically our terms of reference are:

1. To review and access why WG 18 had limited success in achieving its terms of reference;
2. To determine the highest priority marine aquaculture and/or ocean ranching science needs (< 10) for the next 5–10 years in each PICES member country;
3. To develop recommendations for joint activities in marine aquaculture and/or ocean ranching using the PICES Action Plan format;
4. To provide its draft report by September 2007 and be prepared to discuss and finalize the report at PICES XVI (October 2007, Victoria, Canada).

I would like to address these one at a time and propose that we get started as outlined below. Let me know your comments and concerns.

TOR #1: To review and access why WG 18 had limited success in achieving its terms of reference

I would like this group to spend the least amount of time on this issue. I have already sent an e-mail to the members of WG 18 asking for their input on this. When I hear back from most of WG 18, I will summarize this and include it in the report. Those of you who were on WG 18 and are also on this SG, please respond to my other e-mail and then help me to review the draft of the report that I will send out this spring, once I have input from the WG 18 members.

TOR #2: To determine the highest priority marine aquaculture and/or ocean ranching science needs (< 10) for the next 5–10 years in each PICES member country

I think this will be the most important and rewarding part of our work. I would like to approach this in the following manner. By April 2nd, I would like to have each member send me a short list with justification of the top 10 priorities for the next 5–10 years from your own countries' point of view. By the end of April, I will incorporate these into a draft to circulate back to you. I would then like to have an e-mail discussion to develop the final list and justifications. Please feel free to seek the input of your countrymen and others on this topic. In discussions with John Stein, PICES Science Board Chairman, this appears to be the most important part of our work. I would like to be mostly finished with this part by the end of May so we have time to devote to TOR 3.

TOR #3: To develop recommendations for joint activities in marine aquaculture and/or ocean ranching using the PICES Action Plan format

First of all, I had to look up what the PICES Action Plan format was. I have attached the Action Plans for MEQ and FIS (the original parent committees for WG 18) for your information. They basically have four parts: 1) a Mission Statement, 2) a Strategy Statement, 3) a list of goals and 4) Actions to achieve the goals. The work we do under TOR 2 should relate to our list of goals. So the main effort under this item is to come up with actions to achieve the goals. Once those are in place, the mission and strategy should be fairly easy to write. I would like to have this part done by the end of June. We should be able to do this with an e-mail discussion. I will try to capture the ideas and add them to the draft and have the "complete" first draft by mid-July. This should allow time for each SG member to circulate the draft, provide input and edits long before the document is due in September and the presentation in October.

TOR #4: To provide its draft report by September 2007 and be prepared to discuss and finalize the report at PICES XVI (October 2007, Victoria, Canada)

Note the document is due in September. I have a very busy late summer (August–September), so it will be difficult for me to complete the document if we delay the time schedule. The PICES Annual Meeting is in October. I plan on attending, and hope most of the group can also be there. If anyone wants to volunteer to give the presentation let me know. We can work on the presentation in September.

For now the first deliverable that we need to work on is for TOR 2 above. Please compile a list of the top 10 priorities for the next 5–10 years from your own countries point of view. Then please add a short explanation of why they are high priority. You should not feel constrained to considering environmental impacts of aquaculture for this exercise. This is due to me by April 2, 2007. I plan on also calling some colleagues in Europe to determine what our sister organization, ICES, has as priorities in aquaculture and will provide a short summary.

Finally, I have attached a copy of the PICES Strategic Plan and added the link to our study group at the bottom of this message. The PICES Strategic Plan might help in framing your thoughts as we get going. Thank you all for agreeing to participate on this Study Group. I look forward to hearing your thoughts!

Sincerely,

Michael B. Rust Ph.D.
Northwest Fisheries Science Center
2725 Montlake Blvd E
Seattle, WA 98112 USA

http://www.pices.int/members/study_groups/SG-MAR.aspx

SG-MAR Endnote 4

Aquaculture priorities (unedited) for the next ten years provided by PICES member countries

Countries are not identified and no priority is implied by the order in which the priorities appear in the following.

Development of efficient technologies to grow bivalves, echinoderms, algae, and salmons with additional commodity output and to restore the abundance of valuable commercial species. The development of both intensive (farm) and extensive methods of cultivation is planned. At the present stage, hydrocole cultivation technique is mastered and the conditions (including trophic ones) for the accelerated production of biomass have been provided.

Ecological aspects
For working-out of strategies of the sustainable development of marine aquaculture within the coastal waters, the potentialities of the water areas should be assessed taking into account their carrying capacity for different trophic groupings of hydrocoles (filter feeders, detritophages, phytophages). It is also necessary to perform a zoning of the coast and to provide the possible schemes of poly-cultural farms of mariculture under different conditions of the coastal areas.

Assessment of risks in the mariculture activities which can be combined into climatic, ecological and economic groups.

Monitoring of environmental factors
In these days, global warming is the most serious problem worldwide. It brought on a lot of changes of environmental factor. These changes also lead to the variation of oceanic ecosystem and also produce change of carrying capacity in specific area. According to this result we must choose what species are appropriate releasing species and what kind of ranching we make. Therefore first of all, we need monitoring of environmental factors.

Estimation of carrying capacity
To develop marine ranching places, we have to estimate the carrying capacity of objective area. Because when we know the exact carrying capacity, we can decide the releasing amount of fisheries resources, artificial reefs and also how

much we have to increase the productivity in coastal area.

Estimate the amount of natural resources

To perform the marine aquaculture and/or ocean ranching, we should estimate the biomass. We can determine it by the investigation of the fisheries capture amount, species, and size in which we are supposed to make marine ranching places. After those investigations, we can decide the TAC (Total Allowance Catch) more exactly, and also we can decide the capture size and time of releasing fisheries resources.

Examine the effect of discharged resources

At first we have to know appropriate feeds amount for releasing fisheries resources and sustaining ecosystem. We also have to release the fisheries resources when they can adjust their releasing environment through the adjustment periods. If we discharge the resources, we have to monitor the effect of those releasing seeds whether they have some effect in their releasing region.

Provision of self-regulation for fisheries resources management

Most of all, to perform the marine ranching places; it is the important thing, which the fisherman has to have provision of self-regulation for fisheries resources management. If they control their capture amount, size and periods for resources management by themselves, we can perform the marine ranching program very effectively.

Development of alternative income sources for fisherman

To avoid excessive capture, we need development of alternative income sources for fisherman. When they have another income sources in the sea, they will make an effort to sustain ocean resources. Therefore we are considering about the developing of alternative income sources by formation of ocean tourism and leisure industries in the place of marine ranching. It also need infrastructure to make tourist city.

Diseases of aquatic organisms

Investigating disease transmission (bi-directional) between wild and cultured stocks and developing aquaculture vaccines.

Improve disease diagnostics and control

Medical-prophylactic measures in mariculture farms and plantations take on special significance in connection with expanded cultivation. The necessary research studies are: 1) prophylaxis, diagnostics, treatment of infections and immune resistance elevation of marine hydrocoles under conditions of the farm cultivation; 2) micro-biological and eco-toxicological monitoring of the coastal waters condition within zones of commercial plantations of mariculture. Estimation of physiological state of marine hydrobionts under conditions of aquaculture farms and wild populations.

Modeling aquaculture in the ecosystem

Developing biological and oceanographic models, collecting lab and field data to allow prediction of ecological effects (near and far-field) of aquaculture, and determining carrying capacity of aquaculture areas.

Environmental risk assessment

Assessing the risk of genetic and ecological interaction between cultured, enhanced (*e.g.*, hatchery) and wild fish, developing technology to minimize wild/cultured fish interactions, and assessing efficacy of captive breeding programs for endangered stock rebuilding.

Assessing the impact of aquaculture on species at risk

Culture technology development

Developing high-efficiency, environmentally-friendly, and industry-diversifying culture technologies for salmon, alternate fish, shellfish, and algal species.

Biotechnology

Using biotechnology, genomics, and genetics to improve commercially important traits (*e.g.*, growth and reproduction) and assess changes from wild type for use in risk assessments.

Develop and establish technical and economic feasibility with special emphasis on hatchery development, land based and offshore production systems to support commercial marine aquaculture and enhancement of wild stocks.

Assess environmental impacts of current marine aquaculture production systems and species, including fish and shellfish for both commercial marine aquaculture and enhancement of wild stocks.

Conduct nutrition research involving alternative protein based diets and influence of diet on product quality.

Develop environmental models and GIS tools to aid site selection for new facilities.

Develop technical, hands-on training programs in marine hatchery operations and management to support commercial marine aquaculture and enhancement of wild stocks.

Develop synthesis papers (*i.e.*, executive summary and journal publication) for the following topics: a) environmental impacts of marine production systems; b) alternative protein feeds and potential impacts; and c) disease transmission from aquaculture to wild stocks and *vice versa*, and status of ecologically acceptable treatments and preventives; and genetic technologies and environmental risk analysis.

Improve stock enhancement technology to minimize damage to ecosystems and bio-diversity.

Evaluate the effect of stocking on resource fluctuations and improve effectiveness of stocking.

Develop marine polyculture (multi-tropic level aquaculture) with a combination of finfish, shellfish and seaweeds.

Improve seed production (hatchery technology) for difficult species such as eel and greater amberjack.

Develop alternatives to fish meal for diets.

Develop automated feeding systems to reduce cost and improve efficiency.

Develop open ocean cage culture technology (off-shore aquaculture).

Develop bluefin tuna culture technology.

Develop selective breeding technology to improve disease resistance, improve growth, improve efficiency and so on.

SG-MAR Endnote 5

Proposal for a Working Group on
***Environmental Risk Assessment and Interactions of Marine Aquaculture* – ERAIMA**

Mission

Develop standard methods and tools to assess and compare likelihood and severity of the environmental impacts of aquaculture. Make recommendations on how to improve highest risk aspects of aquaculture. Develop models to predict and manage aquaculture activities within the carrying capacity of the environment.

Strategy

To hold a joint workshop and training session with the ICES Working Group on *Environmental Interactions of Mariculture* (WGEIM) to develop risk assessment expertise in the PICES region. Hold a follow-up session on carrying capacity of commercial aquaculture. The session would highlight models to predict carrying capacity of commercial aquaculture that can be used for management. Final results to be reported in a white paper and published as a PICES Scientific Report. Maintain contact with ICES on this topic and consider recurring joint meetings.

Goals and actions

1. To develop and standardize risk assessment methods applied to environmental aspects of aquaculture.
2. To hold a joint meeting with ICES in April 2008. This meeting will review a number of issues related to mariculture under the broad themes of sustainability, climate change and marine spatial planning. More specifically, some proposed areas of discussion could include:
   a. Sustainable development – the precautionary approach, uncertainty and risk assessment/risk analysis, indicators of sustainability;
   b. How good is our ability to predict far-field effects and carrying capacity?
   c. Opportunity costs associated with decisions not to allow development;
   d. Adoption/integration and application of risk assessment techniques to PICES region aquaculture industries.
3. To hold a scientific session at PICES XVIII (2009, Korea) on "*Estimation of environmental carrying capacity for commercial aquaculture*" (Convenors TBD). Papers from this session to be published in the PICES Scientific Report series or a journal.
4. Develop a white paper with recommendations on how to improve highest risk aspects of aquaculture. The white paper would also review state of knowledge of tools for risk assessment (Impact models? Carrying capacity models, *etc*.? Can they be applied to the North Pacific?) and make recommendations for the next steps needed to deal with risks from marine aquaculture to the environment. Publish the white paper as a PICES Scientific Report.

SG-MAR Endnote 6

Proposal for a Working Group on *Technology and Management for Aquaculture* – TMA

Mission

To identify and improve aquaculture technologies with the potential for economic and environmental benefits (eco-effective technologies).

Strategy

To hold a joint workshop on technologies and management approaches that has the potential to improve the economic and environmental performance of commercial aquaculture industries and stocking programs. The Working Group will use focused symposia to articulate and improve such technology and approaches.

Goals and actions

1. Based on the prioritized areas developed under SG-MAR TOR #2, hold a symposium on the top areas for commercial and enhancement aquaculture (technology and husbandry development and evaluation of stocking) with the goal of articulating the "state of the art" in each area and providing recommendations for improving the economic and environmental performance of such technologies.
2. To convene a Topic Session at PICES XVII (2008, Dalian, China) on "*Mariculture technology and husbandry for alternate and developing culture species*" (Convenors: Jie Kong and TBD). Papers from this session to be published in the PICES Scientific Report Series or in a journal. Also conduct a 1-day laboratory demonstration, tour or workshop on a topic that is special to China.
3. To hold a session/workshop at PICES XVIII (2009, Korea) on "*Evaluation of stocking technologies to rebuild, and sustain capture fisheries*" (Convenors TBD). Papers from this session to be published in the PICES Scientific Report series or in a journal.