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Report of the

FAO EXPERT WORKSHOP ON CLIMATE CHANGE IMPLICATIONS FOR FISHERIES AND AQUACULTURE

Rome, 7–9 April 2008

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS DOCUMENT

The world's dependence on the capture fisheries and aquaculture sector is threatened not only by misuse of these aquatic resources but also by factors external to the sector, such as pollution runoff, land use transformation, other aquatic resources uses and climatic changes. As significant coastal inhabitants (whether riparian, lacustrine or marine), fishers and fish-farmers are particularly vulnerable to the direct and indirect impacts of predicted climatic changes including changes in physical environments and ecosystems, fish stocks, infrastructure and fishing operations, and livelihoods.

FAO, in recognizing the likely changes to come and the interactions between fisheries and aquaculture, agriculture, and forestry and these changes, held a High-Level Conference on World Food Security: the Challenges of Climate Change and Bioenergy at FAO headquarters in Rome, from 3 to 5 June 2008.[1] This Conference addressed food security and poverty reduction issues in the face of climate change and energy security.

The FAO Fisheries and Aquaculture Department (FI) held an Expert Workshop on Climate Change Implications for Fisheries and Aquaculture, from 7 to 9 April 2008, in order to provide the FAO Conference with a coherent and high quality understanding of the fisheries and aquaculture climate change issues. This Workshop provided inputs into the High-Level Conference and also constitutes a response to the request from the twenty-seventh session of the FAO Committee on Fisheries (COFI) that "FAO should undertake a scoping study to identify the key issues on climate change and fisheries, initiate a discussion on how the fishing industry can adapt to climate change, and for FAO to take a lead in informing fishers and policy-makers about the likely consequences of climate change for fisheries".

The Expert Workshop identified and reviewed the key issues of climate change in relation to fisheries and aquaculture, from the physical changes, the impacts of those on aquatic resources and ecosystems and how these ecological impacts translate into human dimensions of coping and adapting within fisheries and aquaculture. The Workshop also evaluated policy options and activities at the international, regional and national levels that can help minimize negative impacts of climate change, improve on mitigation and prevention, and maintain and build adaptive capacity to climate change.

The Expert Workshop was organized and convened by the FAO Fisheries and Aquaculture Department Working Group on Climate Change, co-chaired by Kevern Cochrane and Cassandra De Young. Indra Gondowarsito and Giovanna Martone provided secretarial and administrative support.

This report includes an overview of the presentations and discussions held during the Expert Workshop and presents the conclusions and recommendations agreed upon by participants. Three background documents commissioned by FAO formed the basis for the technical discussions. The authors of those papers, Neil Adger, Marie-Caroline Badjeck, Manuel Barange, Katrina Brown, Tim Daw, Sena De Silva, Doris Soto and Ian Perry, are thanked for their valuable contributions to the Workshop.

Funding for the Expert Workshop was provided by the governments of Germany, Italy and Norway and IREPA Onlus provided assistance in administering travel and contract details.

[1] See http://www.fao.org/foodclimate/

FAO.
Report of the FAO Expert Workshop on Climate Change Implications for Fisheries and Aquaculture. Rome, Italy, 7–9 April 2008.
FAO Fisheries Report. No. 870. Rome, FAO. 2008. 32p.

ABSTRACT

This Expert Workshop was convened to identify and review the key issues of climate change in relation to fisheries and aquaculture, from the physical changes, the impacts of those on aquatic resources and ecosystems and how these ecological impacts translate into human dimensions of coping and adapting within fisheries and aquaculture. Three comprehensive background documents formed the basis of the technical discussions. The Workshop also evaluated policy options and activities at the international, regional and national levels that can help minimize negative impacts of climate change, improve on mitigation and prevention, and maintain and build adaptive capacity to climate change. The impetus for the Workshop emerged from recommendations of the twenty-seventh session of COFI (2007) as well as to the need to provide inputs into the FAO High-Level Conference on World Food Security: the Challenges of Climate Change and Bioenergy, held in Rome from 3 to 5 June 2008.

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OPENING OF THE MEETING AND ARRANGEMENTS FOR THE SESSION

1. The Expert Workshop on Climate Change Implications for Fisheries and Aquaculture was held in Rome, Italy, from 6 to 9 April 2008.

2. The list of participants in the meeting is shown in Appendix B.

3. The meeting was called to order by Mr Ichiro Nomura, Assistant Director-General, Fisheries and Aquaculture Department, who delivered the opening statement. The text of his statement is reproduced in Appendix C. Mr Alexander Müller, Assistant Director-General, Natural Resources Management and Environment Department, provided information on the FAO High-Level Conference on World Food Security: the Challenges of Climate Change and Bioenergy.

4. Mr Sena De Silva was elected as Chair of the Workshop and Mr James Muir served as Rapporteur.

5. The agenda shown in Appendix A was adopted by the Expert Workshop.

OBJECTIVES OF THE EXPERT CONSULTATION

6. The Expert Workshop identified and reviewed the key issues of climate change in relation to fisheries and aquaculture, from the physical changes, the impacts of those on aquatic resources and ecosystems and how these ecological impacts translate into human dimensions of coping and adapting within fisheries and aquaculture. The Workshop also evaluated policy options and activities at the international, regional and national levels that can help minimize negative impacts of climate change, improve on mitigation and prevention, and maintain and build adaptive capacity to climate change.

REVIEW OF THREE TECHNICAL BACKGROUND DOCUMENTS

7. As a basis for the technical discussions, the Expert Workshop was presented with the following three comprehensive technical background documents:

- *Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture* by Manuel Barange and Ian Perry
- *Climate change and capture fisheries: impacts, adaptation, mitigation, and the way forward* by Tim Daw, Neil Adger, Katrina Brown and Marie-Caroline Badjeck
- *Climate change and aquaculture: impacts, adaptation, mitigation, and the way forward* by Sena De Silva and Doris Soto

8. The Workshop participants commended the authors on their work, provided guidance on improvements to the documents and recommended their publication as an FAO Fisheries Technical Paper.

CONCLUSIONS AND RECOMMENDATIONS

9. After extensive discussion, the Workshop agreed on the following conclusions, summarizing the current state of knowledge on fisheries and climate change, and recommendations. A more detailed synopsis of predicted climate change impacts and measures for mitigation and adaptation within the fisheries and aquaculture sector is attached to this report as Appendix D.

Introduction

10. From the local to global levels, fisheries and aquaculture have a very important role for food supply, food security and income generation. Some 42 million people work directly in the sector, with the great majority in developing countries. Adding those who work in processing, marketing, and distribution and supply industries, the sector supports several hundred million livelihoods. Aquatic foods have high nutritional quality, contributing 20 percent or more of average per capita animal protein intake for more than 2.8 billion people, mostly from developing countries. Aquatic foods are the most widely traded foodstuffs and are essential components in export earnings for many poorer countries. The sector has particular significance for small island states.

11. Climate change is projected to impact broadly across ecosystems, societies and economies, increasing pressures on all livelihoods and food supplies, including those in the fisheries and aquaculture sector. Food quality will have a more pivotal role as food resources come under greater pressure, and the availability and access to fish supplies will become an increasingly critical development issue.

12. The sector differs from mainstream agriculture, and has distinct interactions and needs with respect to climate change. Capture fisheries have unique features of natural resource harvesting linked with global ecosystem processes. Aquaculture complements and increasingly adds to supply, and, though more similar to agriculture in its interactions, has important links with capture fisheries.

13. The demands of growing populations will require substantial increases in aquatic food supply in the next 20 to 30 years, during which period climate change impacts are expected to widen and increase. The primary challenge for the sector will be, in the face of these impacts and the existing development and management constraints, to deliver food supply, strengthen economic output and maintain and enhance food security; while ensuring ecosystem resilience. This will require concerted, collaborative and determined action across all stakeholders, linking private sector, community and public sector agents.

Summary of the dimensions and scales of likely climate change impacts on fisheries and aquaculture including livelihoods of fishing and fish farming communities

14. Climate change is a compounding threat to the sustainability of capture fisheries and aquaculture development. Impacts occur as a result of both gradual warming and associated physical changes as well as from frequency, intensity and location of extreme events, and take place in the context of other global socio-economic pressures on natural resources. Urgent adaptation measures are required in response to opportunities and threats to food and livelihood provision due to climatic variations.

Ecosystem impacts

- Climate change is modifying the distribution of marine and freshwater species. In general, species are being displaced towards the poles and are experiencing changes in the size and productivity of their habitats. This provides challenges but also opportunities.
- In a warmed world, ecosystem productivity is likely to be reduced in most tropical and subtropical oceans, seas and lakes and increased in high latitudes. Increased temperatures will affect fish physiological processes resulting in both positive and negative effects on fisheries and aquaculture systems.

- Climate change is already affecting the seasonality of particular biological processes, radically altering marine and freshwater food webs, with unpredictable consequences for fish production. Increased risks of species invasions and spreading of vector-borne diseases provide additional concerns.
- Differential warming between land and oceans and between polar and tropical regions will affect the intensity, frequency and seasonality of climate patterns (e.g. El Niño) and extreme events (e.g. floods, droughts, storms) affecting the stability of marine and freshwater resources adapted to or affected by these.
- Sea level rise, glacier melting, ocean acidification and changes in precipitation, groundwater and river flows will significantly affect coral reefs, wetlands, rivers, lakes and estuaries, requiring adapting measures to exploit opportunities and minimise impacts on fisheries and aquaculture systems.

Impacts on livelihoods

- Changes in distribution, species composition and habitats will require changes in fishing practices and aquaculture operations, as well as in the location of landing, farming and processing facilities.
- Extreme events will also impact on infrastructure, ranging from landing and farming sites to post-harvest facilities and transport routes. They will also affect safety at sea and settlements, with communities living in low-lying areas at particular risk.
- Water stress and competition for water resources will affect aquaculture operations and inland fisheries production, and are likely to increase conflicts among water-dependent activities.
- Livelihood strategies will have to be modified for instance with changes in fishers migration patterns due to changes in timing of fishing activities.
- Reduced livelihood options inside and outside the fishery sector will force occupational changes and may increase social pressures. Livelihood diversification is an established means of risk transfer and reduction in the face of shocks, but reduced options for diversification will negatively affect livelihood outcomes.
- There are particular gender dimensions, including competition for resource access, risk from extreme events and occupational change in areas such as markets, distribution and processing, in which women currently play a significant role.

Implications for food security

15. Climate change will have potentially significant impacts on the four dimensions of food security, with changes as follows.

Availability of aquatic foods will vary, positively and negatively, through changes in habitats, stocks and species distribution. These changes will occur at local and regional levels in inland, coastal and marine systems, due to aquatic ecosystem shifts and impacts on aquaculture.

Stability of supply will be impacted by changes in seasonality, increased variance of ecosystem productivity, increased supply risks and reduced supply predictability – issues that may also have large impacts on supply chain costs and retail prices.

Access to aquatic foods will be affected by changes in livelihoods and catching or culture opportunities combined with transferred impacts from other sectors (i.e. increased prices of substitute foods), competition for supply, and information asymmetries. Impacts may also arise from rigid management measures that control temporal and spatial access to resources.

Utilization of aquatic products and the nutritional benefits produced will be impacted by: changes in range and quality of supply; market chain disruptions; greater food safety issues; and reduced opportunities to consume preferred products. This is particularly critical for countries with high per capita fish consumption.

16. Food security will also be positively affected by increasing the percentage of fish used for direct human consumption (versus fish used for feed) and reducing post-harvest losses through spoilage and waste. Climate change will add to the complexity of addressing these issues and climate events may have a direct negative impact on the control of spoilage and waste.

Summary of achievable climate change mitigation measures

17. The primary mitigation route for the sector lies in its energy consumption, through fuel and raw material use, though as with other food sectors, management of distribution, packaging and other supply chain components will also contribute to decreasing the sector's carbon footprint.

- Greenhouse gas contributions of fisheries, aquaculture and related supply chain features are small when compared with other sectors but, nevertheless can be improved, with identifiable measures already available. In many instances, climate change mitigation could be complementary to and reinforce existing efforts to improve fisheries and aquaculture sustainability (e.g. reducing fishing effort and fleet capacity in order to reduce energy consumption and carbon emissions).
- Technological innovations could include energy reduction in fishing practices and aquaculture production and more efficient post-harvest and distribution systems. There may also be valuable interactions for the sector with respect to environmental services (e.g. maintaining the quality and function of coral reefs, coastal margins, inland watersheds), and potential carbon sequestration and other nutrient management options, but these will need further research and development (R&D). The sustainable use of genetic diversity, including through biotechnologies, could have particular efficiency impacts (e.g. through widening production scope of low-impact aquaculture species, or making agricultural crop materials or waste products usable for growing carnivorous aquatic species) but would require to be evaluated on wider social, ecological and political criteria.
- Mitigation R&D expenditure will need to be justified clearly by comparison with other sectors whose impacts could be much greater, but policy influence could already be used to support more efficient practices using available approaches.
- Possible negative impacts of mitigation on food security and livelihoods would have to be better understood, justified where relevant, and minimized.

Summary of key climate change adaptation measures

18. Although resource-dependent communities have adapted to change throughout history, projected climate change poses multiple additional risks to fishery dependent communities that might limit the effectiveness of past adaptive strategies. Adaptation strategies will require to be context and location specific and to consider impacts both short-term (e.g. increased frequency of severe events) and long-term (e.g. reduced productivity of aquatic ecosystems). All three levels of adaptation (community, national and regional) will clearly require and benefit from stronger capacity building, through awareness raising on climate change impacts on fisheries and aquaculture, promotion of general education, and targeted initiatives in and outside the sector.

- Options to increase resilience and adaptability through improved fisheries and aquaculture management include the adoption as standard practice of adaptive and precautionary management. The ecosystem approaches to fisheries (EAF) and to aquaculture (EAA) should be adopted to increase the resilience of aquatic resources ecosystems, fisheries and aquaculture production systems, and aquatic resource-dependent communities.
- Aquaculture systems, which are less or non-reliant on fishmeal and fish oil inputs (e.g. bivalves and macroalgae), have better scope for expansion than production systems dependent on capture fisheries commodities.
- Adaptation options also encompass diversification of livelihoods and promotion of aquaculture crop insurance in the face of potentially reduced or more variable yields.
- In the face of more frequent severe weather events, strategies for reducing vulnerabilities of fishing and fish farming communities have to address measures including: investment and capacity building on improved forecasting; early warning systems; safer harbours and landings; and safety at sea. More generally, adaptation strategies should promote disaster risk management, including disaster preparedness, and integrated coastal area management.
- National climate change adaptation and food security policies and programmes would need to fully integrate the fisheries and aquaculture sector (and, if non-existent, should be drafted and enacted immediately). This will help ensure that potential Climate change impacts will be integrated into broader national development (including infrastructure) planning.
- Adaptations by other sectors will have impacts on fisheries, in particular inland fisheries and aquaculture (e.g. irrigation infrastructure, dams, fertilizer use runoff), and will require carefully considered trade-offs or compromises.
- Interactions between food production systems could compound the effects of climate change on fisheries production systems but also offer opportunities. Aquaculture based livelihoods could for example be promoted in the case of salination of deltaic areas leading to loss of agricultural land.

Recommendations

Developing the knowledge base

19. The existing pressures of demand, and anticipated challenges, will require better multiscale understanding of the impacts of climate change and of the interacting contribution of fisheries and aquaculture to food and livelihoods security. Climate change will increase uncertainties in the supply of fish from capture and culture. Such uncertainty will impose new challenges for risk assessment, which is commonly based on knowledge of probabilities from past events. Data for determining effects of past climate change at best cover no more than a few decades, and may no longer be an adequate guide to future expectations.

20. This means that, in the future, planning for uncertainty will need to take into account the greater possibility of unforeseen events, such as the increasing frequency of extreme weather events and "surprises". However, at the same time, examples of past management practices in response to existing climate variability and extreme events relating to different regions and resources can provide useful lessons to design robust and responsive adaptation systems, even though they will have to be placed in context of greater uncertainty.

21. While current knowledge is adequate in many instances to take appropriate action, better communication, application and feedback will be essential in knowledge-building.

Action in the following areas will be needed to support mitigation and adaptation policies and programmes in fisheries and aquaculture:

Estimate production levels. Projections of future fisheries production levels at the global and regional scales will be driven by medium- and long-term probabilistic climate change predictions in the context of substantial ecological and management uncertainties.

Forecast impact levels. Detailed impact predictions on specific fisheries and aquaculture systems will be required to determine additional positive or negative consequences for vulnerable resources and regions. This is particularly important for semi-arid countries with significant coastal or inland fisheries, as they are among the most vulnerable to climate change.

Develop tools for decision-making under uncertainty. Adaptive tools for the fisheries and aquaculture sectors will need to be refined, developed and implemented to guide decision-making under uncertainty and address important cross linkages among the relevant sectors. The uncertainties decision-makers will face include: i) the responses and adaptations of marine and freshwater production systems to gradual climate change, including critical thresholds and points of no return; ii) the synergistic interactions between climate change and other stressors such as water use, eutrophication, fishing, agriculture, alternative energy; and iii) the ability and resilience of aquatic production systems and related human communities to adapt and cope to multiple stresses.

Expand societal knowledge. Better knowledge will be required of who is or will be vulnerable with respect to climate change and food security impacts, how this arises and how it can addressed. In this regard, gender and equity issues will need to be carefully considered.

Policy, legal and implementation frameworks at national, regional and international levels

22. Addressing the potential complexities of climate change interactions and their possible scale of impact requires mainstreaming of cross-sectoral responses into governance frameworks. Responses are likely to be more timely, relevant and effective if they are brought into the normal processes of development and engage people and agencies at all levels. This requires not only the recognition of climate-related vectors and processes, and their interaction with others, but also availability of sufficient information for effective decision-making and approaches that engage public and private sectors. All of these elements will be vital in providing the best possible conditions in which the aims of food security – quantity and timing of food supply, access and utilization – can be met.

National. Action plans at the national level can have as their bases the Code of Conduct for Responsible Fisheries and related International Plans of Action (IPOAs), as well as appropriately linked policy and legal frameworks and management plans. Responses will need to employ integrated ecosystem-based approaches to fisheries and aquaculture (EAFs and EAAs) for the national fisheries and aquaculture sector throughout the entire resource extraction, supply and value chain. The future implications of climate change will intensify the justification for finding policy consensus to reform capture fisheries while respecting national sector characteristics.

- Actions will be needed that focus on key issues such as adjusting fleet and infrastructure capacity and flexibility, identifying management systems that offer negotiated balances between efficiency and access, and creating alternative employment and livelihood opportunities.

- Policy and legal regulatory frameworks will be required for aquaculture to expand along sustainable and equitable development paths.
- Links will need to be improved among fisheries, aquaculture and other sectors that share or compete for resources, production processes or market position, in order to manage conflicts and ensure that food security aims can be maintained.
- Links will be required among national climate change adaptation policies and programmes as well as national cross-sectoral policy frameworks such as those for food security, poverty reduction, emergency preparedness and response, insurance and social safety schemes, agricultural and rural development, and trade policies.

Regional. The potential for spatial displacement of aquatic resources and people as a result of climate change impacts, and the greater variability characteristics of transboundary resources will require existing regional structures and processes to be strengthened or given more specific focus. Policy and legal mechanisms that address these issues will need to be developed or enhanced. Regional market and trading mechanisms are also likely to be more important in linking and buffering supply variability and maintaining sectoral value and investment.

- Regional fisheries organizations and other regional bodies should be strengthened. They should place climate change awareness and response preparedness clearly on their agendas and link more closely with related regional bodies.
- Fisheries and aquaculture will need to be addressed adequately in cross-sectoral and transboundary resource use planning and in intraregional markets and trade. In this vein, the potential effects of climate change stressors on regional issues will have to be considered as part of any provisions for action.
- Common platforms are needed for research and data gathering approaches, sharing of best practices in identifying and responding to climate change-related impacts and developing response mechanisms.

International. As sectoral trade and competition issues link with climate change mitigation and adaptation activities, they are likely to become more important, with the potential to define many areas of economic potential and constraint. As a small and often politically weak sector, fisheries and aquaculture may be particularly vulnerable in such competition and conflicts. This increases the importance of having fishery sector representation in policy and legal development processes related to climate change mitigation and adaptation.

- Fisheries and aquaculture need to be adequately addressed in climate change policies and programmes dealing with global commons, food security and trade.
- Common platforms are needed for international data and research approaches, sharing best practices in identifying and responding to climate change-related impacts and developing response mechanisms.
- Fishery sector responses should be incorporated into processes and decisions related to climate change in the other major sectors (e.g. water) to which fishery issues are linked.
- International fishery agreements and conventions should be more vigorously applied, and strengthened if necessary, to accommodate and support climate change-related activities.
- Cooperation and partnerships should be enhanced for dealing with NGOs, civil society organizations, intergovernmental organizations, including the 1-UN approach, and donor coordinated initiatives.

Capacity building: technical and organizational structures

23. Policy-making and action planning in response to climate change involves not only the technically concerned line agencies, such as departments responsible for fisheries, interior affairs, science, and education, but also those for national development planning and finance. These institutions, as well as community or political representatives at subnational and national level should also be identified to receive targeted information and capacity building. Partnerships would also need to be built and strengthened among the public, private, civil society and NGO sectors.

- Nationally, information gaps and capacity building requirements will have to be identified and addressed through networks of research, training and academic agencies
- Internationally, networks should be created or developed to encourage and enable regional or global exchange of information and experience, linking fishery sector issues with others including water management, community development, trade and food security.
- Existing management plans for the fisheries and aquaculture sector, coastal zones or watersheds should be reviewed and, if needed, developed to ensure that they cover potential climate change impacts, mitigations and adaptation responses. Connections with wider planning and strategic processes also need to be identified and adjusted.
- Communication and information processes that reach all stakeholders will be essential elements in sectoral response. This will require focused application by communication specialists to ensure that the information is accessible and usable – presenting diverse and complex issues in a form that is targeted and understandable for specific audience.

Enabling financial mechanisms: embodying food security concerns in existing and new financial mechanisms

24. The full potential of existing financial mechanisms will be needed to tackle the issue of climate change. Innovative approaches may also be needed to target financial instruments and to create effective incentives and disincentives. The public sector will have an important role in levering and integrating private sector investment interacting through market mechanisms to meet sectoral aims for climate change response and food security. Many of these approaches are new and will need to be tested in the sector.

At the national level:

- Producers, distributors and processors should be able to increase self protection through financial mechanisms. This is particularly relevant for aquaculture (e.g. cluster insurance) but financial services could also be used to promote emergency funds more widely through the sector.
- Investment in the sector, especially in infrastructure, will need to consider climate change, which will require developing better information on the costs and benefits of protection.
- Transfer or spread of sector-related risk – from individuals and communities to the state through contingency plans – will be based on specific fiscal provisions but also may be tied to innovations in resource management through which the insured accept responsibilities in exchange for protection.
- Financial instruments that can promote risk reduction and prevention practices include initiatives such as relocation allowances from low lying areas and disincentives for misuse of water in aquaculture.
- Existing and new initiatives for improving equity and economic access, such as microcredit, should be linked to climate change adaptation responses such as livelihood diversification.
- Mitigation options can include fiscal incentives for reducing the sector's carbon footprint, developing more efficient processes and sector agreements, and providing payment for

environmental services, particularly offering additional livelihood options to poorer communities.

At the international level:

- Funding agencies can “climate proof” their approaches and, at the same time, take advantage of new opportunities in the fisheries and aquaculture sector by jointly promoting food security, reducing negative impacts of climate variability and change, and improving resource management.
- Donors should be made more aware of the importance of the fisheries and aquaculture sector in terms of food security and its sensitivity to climate change, and of effective ways in which the sector could become part of cross-sectoral investment strategies.
- Private sector investors should be encouraged to incorporate “climate proof” approaches into international sourcing, trade and market development, and into broader corporate responsibility areas, including delivery of local benefits and inclusion of smaller scale producers.

CLOSING OF MEETING

25. After agreeing on the conclusions and recommendations, the Workshop was closed at 19:00 hours on 9 April 2008.

APPENDIX A

Agenda

Opening of the meeting and arrangements for the session

Objectives of the Expert Workshop

Review of background documents:

Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture

Climate change and capture fisheries – impacts, adaptation,

Climate change and aquaculture – impacts, adaptation, mitigation, and the way forward

Contributions towards Code of Conduct technical guidelines on the economic, social and institutional considerations of applying the ecosystem approach to fisheries

Drafting of Synthesized technical report and decision-makers options paper

Recommendations

Adoption of the report

APPENDIX B

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APPENDIX C

Welcoming address by Mr Ichiro Nomura, Assistant Director-General, FAO Fisheries and Aquaculture Department

Ladies and Gentlemen,

Welcome to Rome, and Welcome to FAO.

I am pleased to welcome you to this Workshop on Climate Change Implications for Fisheries and Aquaculture. I would like to thank you all for joining this Workshop, and express my gratitude for your agreement in serving as experts.

As you may know, the FAO Fisheries and Aquaculture Department mission is "to facilitate and secure the long-term sustainable development and utilization of the world's fisheries and aquaculture resources". This implies necessarily an awareness of the characteristics and limits of the resources and ecosystems as and of the fundamental social and economic role which is played by the fisheries sector in meeting basic objectives such as: fostering global and national sustainable food security, alleviating poverty in fishing and rural communities through employment, and generating national income.

The attainment of the goal of sustainable development and utilization is being constantly threatened by a multitude of factors from within the fisheries sector and from without. Climate change is one of those factors and global concern about the future magnitude and impacts of climate change has been growing in recent years, driven in large part by the increasingly disturbing results from the Intergovernmental Panel on Climate Change, based on the best available knowledge. As the majority are coastal inhabitants, fishers and fish-farmers are particularly vulnerable to the direct and indirect impacts of predicted climatic changes including changes in physical environments and ecosystems, fish communities, infrastructure, fishing and aquaculture operations, and livelihoods.

As background to this Workshop, during the twenty-seventh session of COFI, that is the FAO Committee on Fisheries, which took place in March 2007, it was requested that "FAO should undertake a scoping study to identify the key issues on climate change and fisheries, initiate a discussion on how the fishing industry can adapt to climate change, and for FAO to take a lead in informing fishers and policy-makers about the likely consequences of climate change for fisheries".

The subject was again raised during the thirty-fourth session of the FAO Conference, which "expressed particular concern over the impact of climate change, especially on the poorest and most vulnerable countries and populations" and that "agriculture, while itself contributing to greenhouse gas emissions, was also likely to be one of the sectors most affected by climate change and could also offer possible solutions". In this regard, the Conference stressed the need for strategies to advert and mitigate the effects of climate change and emphasized the importance of sustainable management of fisheries".

In addition, FAO, in recognizing the likely changes to come and the role that fisheries and aquaculture, agriculture, and forestry play in these changes, will hold a High Level

Conference on World Food Security: the Challenges of Climate Change and Bioenergy at FAO headquarters in Rome from 3 to 5 June 2008. This Conference will address food security and poverty reduction issues in the face of climate change and energy security. With a view to providing the Conference with information and advice on sector response strategies and assisting with emerging demands from countries, FAO has been assembling the best available knowledge and tapping relevant networks through a series of multisectoral expert workshops. Recognizing that fisheries and aquaculture are of special food security importance to almost three billion people who depend on these resources as a significant source of protein and hundreds of millions that are linked to fisheries and aquaculture as a form of livelihood, the sector was accorded its own expert workshop within the High Level Conference preparations.

The objective of this Workshop is to identify and review the key issues on climate change in relation to fisheries and aquaculture, from the physical changes, the impacts of those on aquatic resources and ecosystems and how these ecological impacts translate into human dimensions of coping and adapting within fisheries and aquaculture. The workshop will also evaluate policy options and activities at the international, regional and national levels that can help minimize negative impacts of climate change, improve on mitigation and prevention, and maintain and build adaptive capacity to climate change. Your contribution over the next few days in assisting FAO to achieve this objective will be very valuable.

Your task in the upcoming days will be to provide a review of the three background reports that have been prepared for this meeting, identify the key issues that the fisheries and aquaculture sector will face in the near to mid-term future, and to propose practical responses to these issues. The work done here will inform the High Level Conference and the international community at large of the high-priority policy actions necessary to promote resilient and sustainable fisheries and aquaculture into the foreseeable future.

I would like to thank you all for taking the time to assist FAO with this task and for providing your wisdom and insights. I wish you a productive experience in the coming days and look forward with interest to the results of your work.

I finally wish to take this opportunity to thank, on behalf of the Organization and of the Fisheries and Aquaculture Department, the governments of Germany, Italy and Norway for their support in providing the funds necessary for experts' participation and IREPA Onlus for providing invaluable assistance in administering the travel and contract details.

Thank you very much, Ladies and Gentlemen, for your attention.

APPENDIX D

Technical synopsis of climate change implications for fisheries and aquaculture

THE IMPORTANCE OF FISHERIES AND AQUACULTURE TO LIVELIHOODS AND FOOD SECURITY

Fisheries and aquaculture play an important but often unsung role in economies around the world, whether developed or developing. Easily overlooked and often underreported, the following points provide a glimpse of the macroeconomic and microeconomic importance of the sector:

Production and trade of aquatic products:

- Aquatic products are amongst the most widely traded foods, with about 40 percent of world production entering international trade.
- Fishery trade is particularly important for developing countries as a source of foreign currency. At present, their net earnings from aquatic products are greater than the combined earnings from the major agricultural commodities of rice, coffee, bananas, rubber, sugar and tea.
- Capture fisheries production in 2006 was 92 million tonnes, a small decline from 2005, and is not expected to increase much further, with most stocks reaching or sometimes exceeding capacity limits, though the net quantity for human consumption may rise.
- Aquaculture production was 51.7 million tonnes in 2006, and continues to grow more rapidly than all other animal food-producing sectors, with a global average annual growth rate of 8.8 percent per year since 1970, compared with 2.8 percent for terrestrial farmed meat production systems.
- If growth in aquaculture can be sustained it is likely to fulfil the increasing demand for aquatic food supplies by supplying more than 50 percent of the total aquatic food consumption by 2015.

Contribution to GDP and livelihoods:

- The contribution made by the fisheries and aquaculture sector to Gross Domestic Product (GDP) typically ranges from around 0.5 to 2.5 percent, but may exceed 7 percent in some countries; this often compares very significantly with agricultural sector GDP.
- Millions of people around the world depend on fisheries and aquaculture, directly or indirectly, for their livelihoods. Currently, an estimated 42 million people work full or part time as fishers and fish farmers, with the great majority in developing countries, principally in Asia. Furthermore, hundreds of millions of other people work in the sector as occasional fishers or in associated activities including supply and post-harvest services, marketing and distribution.
- Growth in sector employment has largely outpaced that of agriculture and has been mainly in small-scale fisheries and in the aquaculture sector in the developing world, where it has been noted to have important seasonal income, food supply and security impacts.

Fishery products and food security:

- Fish[1] is highly nutritious, rich in micronutrients, minerals, essential fatty acids and proteins, and represents a valuable supplement to diets otherwise lacking essential vitamins and minerals; these nutrients have particular importance in natal and child health and development.
- Fish products provide more than 2.8 billion people (2.6 billion of whom are from developing countries) with about 20 percent of their average per capita intake of animal protein.
- Fish contributes to, or exceeds, 50 percent of total animal protein intake in some small island and other developing States.

The responsible management of the resources and ecosystems on which this important sector depends, is itself a major challenge for world food security. However, the sector is also threatened by external factors, including pollution runoff, land use transformation, and competing aquatic resource uses, to which the impacts of climate changes could have an important compounding effect. The many people dependent on fisheries and aquaculture, as producers, consumers or intermediaries, in inland or coastal

[1] “Fish” refers to all aquatic food products including all invertebrate groups (e.g. crustaceans, molluscs etc.)

areas will be particularly vulnerable to the direct and indirect impacts of predicted climatic changes, whether through changes in physical environments, ecosystems or aquatic stocks, impacts on infrastructure and fishing or farming operations, or options for livelihoods.

This summary document reviews the predicted impacts of climate change on physical and ecological features of aquatic systems and their impacts on the fisheries and aquaculture sector, the role the sector has to play in climate change mitigation, and the opportunities and threats to people and communities dependent on the sector as determined by their vulnerability and potential for adaptation.

Why separate out climate change implications for fisheries and aquaculture from other food production systems?

Wild capture fisheries are fundamentally different from other food production systems in their linkages and responses to climate change and in the food security outcomes. Aquaculture also has strong dependent linkages to capture fisheries, and both of these feed into distinct and specialized post harvest and market chains. Conclusions on food supply and security derived from terrestrial contexts cannot usually be applied directly to the sector, and special consideration is needed to ensure policy and management responses are effective.

For example, most fishing depends on wild populations, whose variability depends on environmental processes governing the supply of young stock, and feeding and predation conditions through the life cycle. Open water populations cannot be simply enhanced by adding fertilizers as in agriculture, nor can effects of environmental change be quickly observed. Many fish populations migrate over long distances, passing through multiple territorial waters. This creates issues of transboundary management, control and utilization, driven by natural environmental factors. Climate change impacts could change resource access “winners” and “losers”, at both community and national level.

Unlike most terrestrial animals, all aquatic animal species for human consumption are poikilothermic (i.e. have body temperatures that vary with the ambient temperature). Consequently, changes in habitat temperatures significantly influence metabolism, and hence growth rate, total production, reproduction seasonality and possibly reproductive efficacy, and susceptibility to diseases and toxins. Climate change-induced temperature variations will therefore have a much stronger impact on the spatial distribution of fishing and aquaculture activities and on their productivity and yields.

Much fishing is still an open access activity and non-boat based fisheries require little capitalization (e.g. collecting clams on a beach, or using handlines or simple bamboo traps in ricefields). It can therefore often function as a last-resort activity, or to supplement food supply when other sources are weak, playing an important role in adaptive strategies. However, there are potential mismatches between these important social objectives and the fisheries management concerns of over-exploitation of resources, and the need to limit access or to restrict fishing to particular species, places or times.

Climate change is only one among many environmental and anthropogenic stresses faced by fisheries and aquaculture but is likely to exacerbate the difficulties of achieving sustainable practices. However, the magnitude and direction of climate change-specific stressors will vary from one aquatic system to another, or may play only a small role when compared with other stressors. Climate change may also offer win-win outcomes where adaptation or mitigation measures improve economic efficiency and resilience to climatic and other change vectors (e.g. decreasing fishing effort to sustainable levels, decreasing fuel use and hence CO_2 emissions, or reducing aquaculture dependence on fishmeals/oils).

PHYSICAL AND ECOLOGICAL IMPACTS OF CLIMATE CHANGE ON MARINE AND INLAND ECOSYSTEMS AND FISHERY RESOURCES

This section summarizes the potential physical and ecological impacts of climate change on aquatic systems. As more information develops, more detailed documentation of regional and local climatic impacts will further assist in determining ecological, supply or food security hotspots.

Changes in physical environments

Marine waters

Higher frequency and intensity climate processes (e.g. El Niño-Southern Oscillation [ENSO]) and decadal-scale regime shifts, are expect to continue, but it is unclear so far whether they will retain or change their present characteristics. The oceans are warming, but with geographical differences and some decadal variability. Warming is more intense in surface waters but is not exclusive to these, with the Atlantic showing particularly clear signs of deep warming.

Changes in ocean salinity have been observed, with near-surface waters in the more evaporative regions increasing in salinity in almost all ocean basins, and high latitudes showing a decreasing trend due to greater precipitation, higher runoff, ice melting and advection. The oceans are also becoming more acidic, with likely negative consequences to many coral reef and calcium-bearing organisms. Although there are no clearly discernable net changes in ocean upwelling patterns, there are indications that their seasonality may be affected.

Global average sea level has been rising since 1961 and this rate has accelerated since 1993. Although not geographically uniform, large coastal land losses are likely on the Atlantic and Gulf of Mexico coasts of the Americas, the Mediterranean, the Baltic, and small-island regions, while in other areas (e.g. Asia) large and heavily populated deltaic regions may also be strongly impacted

Inland waters

There has so far been no global assessment of warming of inland waters but many lakes have shown moderate to strong warming since the 1960s. There are particular concerns in African lakes, as the atmospheric temperature of the continent is predicted to be higher than the global average and rainfall is projected to decrease. Likewise, wetlands and shallow rivers are susceptible to changes in temperature and precipitation and water levels may drop to the point of drying out more completely in dry seasons. Increased temperature may lead to stronger, earlier and longer stratification of lakes and reservoirs and with limited or no seasonal turnover, greater deoxygenation of bottom layers.

River run-off is expected to increase at higher latitudes but decrease in parts of West Africa, southern Europe and southern Latin America. Overall, a global temperature increase of 1°C is associated with a four percent increase in river run-off. Changes in flood areas, timing, and duration are also expected.

Changes in biological functions/fish stocks

Marine waters

Although large differences exist, especially at regional scales, most models predict decreasing primary production in the seas and oceans and many models predict composition shifts to smaller phytoplankton which are likely to lead to changes in food webs in general. Changes in fish distributions in response to climate variations have been observed. Most rapid changes occur with pelagic species. Reactions to past warming events have been poleward expansions of warmer-water species and poleward contractions of colder-water species.

Inland waters

In general, temperature changes are likely to impact cold-water species negatively, warm-water species positively, and cool-water species positively in their northern ranges and negatively in their southern ranges. There will likely also be a general shift of cool- and warm-water species northward in northern hemisphere rivers. The abundance and species diversity of riverine fishes are predicted to be particularly sensitive to climatic disturbances, since lower dry season water levels may reduce the number of individuals able to spawn successfully. The timing of flood events is critical as a physiological trigger that induces fish to migrate and spawn at the onset of the flood; enabling their eggs and larvae to be transported to nursery areas on floodplains.

Ecological forecasts

A range of impacts on aquatic ecosystems can be predicted in association with large-scale changes in temperature, precipitation, winds, and acidification. It is very likely that over the short term (i.e. within a few years), increasing temperatures would have negative impacts on the physiology of fish in that locality through limiting oxygen transport. This would have significant impacts on aquaculture and result in changes in distributions, and probably abundance, of both freshwater and marine species. There is high confidence in predictions that over the medium term (i.e. a few years to a decade), temperature-regulated physiological stresses and changes in the timing of life cycles will impact the recruitment success and therefore the abundances of many marine and inland aquatic populations and species composition of marine and inland communities. There is lower confidence in long-term (i.e. multi-decadal) time scale predictions. Predicted impacts depend upon, amongst other factors, changes in net primary production in the oceans and its transfer to higher trophic levels.

CLIMATE CHANGE IMPACTS ON FISHERIES, AQUACULTURE AND THEIR COMMUNITIES

Overall impacts on fisheries, aquaculture and fishery-dependent communities

Fisheries

The impacts of physical and biological changes on fisheries communities[2] will be as varied as the changes themselves. Both negative and positive impacts could be foreseen, their strength depending on the vulnerability of each community; combining potential impacts (sensitivity and exposure) and adaptive capacity. Impacts would be felt through changes in capture, production and marketing costs, changes in sales prices and possible increases in risks of damage or loss of infrastructure, fishing tools and housing. Fishery-dependent communities may also face increased vulnerability in terms of less stable livelihoods, decreases in availability and/or quality of fish for food, and safety risks, for example, fishing in harsher weather conditions and further from their landing sites. Within communities and households, existing gender issues related to differentiated access to resources and occupational change in markets, distribution and processing, where women currently play a significant role, may be heightened under conditions of stress and competition for resources and jobs stemming from climate change.

Aquaculture

Impacts on aquaculture could also be positive or negative, arising from direct and indirect impacts on the natural resources it requires, primarily water, land, seed, feed and energy. As fisheries provide significant feed and seed inputs, the impacts of climate change on them will also, in turn, affect the productivity and profitability of aquaculture systems. Vulnerability of aquaculture-based communities will stem from their resource dependency and also on their exposure to extreme weather events. As climatic changes could increase physiological stress on cultured stock this would not only affect productivity but also increase vulnerability to diseases, in turn imposing higher risks and reducing returns to farmers. Interactions between fisheries and aquaculture sub-sectors could create other impacts, for example extreme weather events resulting in escapes of farmed stock and contributing to potential reductions in genetic diversity of the wild stock and affecting biodiversity more widely.

These impacts will be combined with other aspects affecting adaptive capabilities, such as the increased pressure that ever larger coastal[3] populations place on resources, any political, institutional and management rigidity that negatively impacts on communities' adaptive strategies, deficiencies in monitoring and early-warning systems or in emergency and risk planning, as well as other non-climate factors such as poverty, inequality, food insecurity, conflict, disease.

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[2] "Communities" as defined in the widest sense possible (i.e. from local fishing communities to large-scale fishing production systems, from suppliers to consumers, and from those that manage to those that are managed).

[3] "Coastal" in this sense refers to lacustrine, riparian and marine coasts.

However, new opportunities and positive impacts (e.g. from changes in species and new markets) could also be part of future changes. So far, these opportunities are not well understood but are nevertheless possible and a community's ability to benefit will also depend on their adaptive capacity.

Specific impacts to food security

Climate change impacts in the sector will potentially act across the four dimensions of food security, that is: availability, stability, access and utilization.

Availability of aquatic products will vary through changes in ecosystems, production, species distribution and habitats. Changes will occur at regional and local levels in freshwater and marine systems due to ecosystem shifts and changing aquaculture options, which depend on availability of key inputs. Production from aquatic resources, whether through fisheries or aquaculture may be impacted by the adaptive capacity of management measures controlling temporal and spatial access.

Stability of supply will be impacted by changes in seasonality, increased variance of ecosystem productivity, increased supply risks and reduced supply predictability – issues that may also have large impacts on supply chain costs and their flexibility to respond to variation.

Access to fish for food will be affected by changes distribution of fish species and in livelihoods combined with transferred impacts from other sectors (i.e. increases in prices of substitute food products), competition for supply, and information asymmetries. Policies and measures tackling climate change impacts may indirectly hamper people's access to food by constraining individuals' expression of their entitlements and rights to food.

Utilization of nutrients (i.e. their nutritional value) from fishery products will be affected through changing supply quality and market chain disruptions. In some cases, a period of adjustment will be required to move to species that are not traditionally consumed. These issues are most critical for countries with a high per capita consumption of aquatic proteins.

Availability of fish for food can be improved by making better use of production by reducing post-harvest losses and increasing the percentage of use for direct human consumption. Losses caused by spoilage amount to about 10 to 12 million tonnes per year and an estimated 20 million tonnes of fish a year are discarded at sea. Climate change will add to the complexity of addressing these issues and climate events may have a direct negative impact on the control of spoilage and waste.

Vulnerability hot spots

The extent to which people and systems are affected by climate change (their vulnerability) is determined by three factors: their exposure to specific change, their sensitivity to that change, and how well they can respond to impacts and/or take advantage of opportunities. The non-linear interactions of these factors mean that vulnerability is unevenly distributed, sometimes in surprising ways. It is important to understand patterns of vulnerability to specify and prioritize adaptation interventions.

Fisheries located in the high latitudes and those which rely on climate change-susceptible systems, such as upwelling or coral reef systems, appear to have most potential exposure to impacts. However, low adaptive capacities are important, elevating the vulnerability of least-developed countries even though greater warming is predicted at higher latitudes. Communities located in deltas, coral atolls and ice dominated coasts will also be particularly vulnerable to sea level rise and associated risks of flooding, saline intrusion and coastal erosion. Coastal communities and small island states without proper extreme weather adaptation programmes, in terms of infrastructure design, early warning systems and knowledge of appropriate behavior, will also be at high risk.

For aquaculture, Asia is by far the major contributor and at present the most vulnerable region. However, recognizing the high growth potential for aquaculture in Africa, Latin American countries and other regions, implications need to be considered in relation to future developments. In deltaic areas in Asia, agriculture is a predominant means of livelihood and contributes significantly to food security. The loss of agriculture productivity due to salination from sea level rise and seawater intrusion, could have an important impact, and lead to aquaculture taking a major adaptive role as an alternative livelihood, compensating for income and some aspects of food supply.

Transboundary issues

The potential spatial displacement of aquatic resources and people associated with climate change impacts, and the greater variability characteristics of transboundary resources, would require existing bilateral and regional structures and processes to be strengthened and/or given more focus. Policy and legal issues will need to be developed. Regional market and trading mechanisms would also be more important in linking and buffering supply variability and maintaining sectoral value and investment.

Current examples of impacts from displacing populations due to climatic variations include, for example, the on-going negotiations between the United States of America and Canada over access to Pacific salmon and Pacific Ocean skipjack tuna resources, whose spatial distributions are largely determined by environmental variability. The potential increase and expansion of aquatic diseases in aquaculture and the expansion of exotic pest species will require specific transboundary actions, particularly in large international watersheds (e.g. Mekong River, the Mediterranean Sea).

Climate change impacts on fisheries and aquaculture from other sectors

Indirect impacts arising from adaptation by other sectors, and from climate change mitigation (e.g. use of alternative energy sources) could be significant and may even overshadow the direct impacts of climate change. An ecosystem approach would be required, and system-wide evaluation and planning of mitigation and adaptation strategies will need to include downstream impacts on other sectors.

Mitigation strategies in other sectors

Offshore wind, wave and tidal energy devices are increasingly being developed for renewable energy, but could have negative impacts. Greater nuclear power capacity is also being proposed, usually with coastal or inland water cooling, and the discharge of heated waters. Construction and operation of all of these systems could affect aquatic resources directly (including spawning, overwintering, nursery and feeding grounds and migratory pathways). In shallow coastal waters they could also interfere with fishing, through structural obstruction and undersea transmission cables. However, suitable siting and construction can give shelter for aquaculture, protection from illegal fishing, opportunities for habitat and stock enhancement, and with heated water, opportunities for enhancing growth and species choice.

New investments in hydropower are also being considered, often combining with water supply regulation. However dams may interrupt connectivity between habitats, preventing fish from completing their life cycles, and impact water flows important for habitat maintenance and as physiological triggers for migration. Flood sizes and duration, which determine size and timing of feeding areas in floodplains, could also be impacted, and reduced flows can have important effects on salinity in and dissolved nutrient supply to coastal ecosystems.

Increased interest in production of biofuels will have a compound impact on crop prices, including impacts on price and availability of feeds for aquaculture. At this stage, aquatic based biofuels, e.g. based on algal sugars, are only experimental, but may in the future lead to negative impacts of resource competition or positive impacts of integration opportunities with various aquaculture systems.

Adaptation strategies in other sectors

Changes to patterns of precipitation, water table conditions, and increasing frequency of extreme flooding in lake and river basins may promote agriculture sector demand for more flood control, drainage and irrigation schemes. These could exacerbate negative impacts of climate change on fisheries and aquaculture. Flood control embankments or levees may constrain river flows, increasing peak and mean discharge rates and flooding events elsewhere. Increased erosion of river beds can reduce fish populations that spawn there. Increased sediment loads can choke spawning substrates, affect reproductive success and block migration routes. Flood control efforts may also reduce the depth and surface area of dry season water bodies, and hence their carrying capacity for critical stocks.

Though some irrigation demand could be met by using reservoirs or abstracting water from surface and ground waters, dry season water is often abstracted from residual pools and water bodies remaining after flood-waters have receded. These provide critical dry season refuge habitat for many floodplain species, and beyond certain thresholds, their production is highly sensitive to water removal. Changing locations of watering points for livestock and adaptive strategies to deal with heat stress may place further strain on dry season fish habitats. Increasing intensity of fertilizer and pesticide application to mitigate impacts of climate change on agriculture could also adversely affect water quality in rivers, lakes and coastal zones, and thereby impact fisheries. These water quality changes may be further exacerbated by the impacts of greater waste concentrations from human settlements, from reduced per capita water use, and from greater risk of disruption of waste treatment processes. Increased agricultural water demand may also constrain aquaculture, not only due to reduced water availability but as aquaculture may have to use irrigation drainage water and experience further reduced water quality.

Soil erosion from changing land use could also cause impact by increasing sediment loads. Greater downstream sediment transport may adversely impact coral reef and other coastal fisheries by affecting light penetration and physiological processes, or interfere with feeding in coastal aquaculture. Increasing sediment may however help sustain river deltas and critical habitats such as mangroves, threatened by rising sea levels and increased storm erosion. However, changes in estuarine salinity distribution brought about by changes to river discharge rates may also be important.

Cumulative effects of human activity and climate change on ecosystem productivity

The resilience of many ecosystems is likely to be exceeded by an unprecedented combination of climate change and other global change drivers. Climate change, pollution, fragmentation and loss of habitat (e.g. destructive fishing activities, coastal zone development), invasive species infestations, and over-harvesting from fisheries may individually or together result in severe impacts on the production of the world’s aquatic systems and the services they provide. The impacts on aquatic life from these stressors may be exacerbated by climatic changes and the ability of ecosystems to recover (resilience) will be impaired. Therefore, the combined effects of these may steadily and some cases possibly sharply increase the vulnerability of the world’s aquatic resources, with important ecological, economic and social implications. In this respect too, the role of fishery sector stakeholders in contributing to the long term health of the resource, not just for food supply and security, but for the continued provision of wider ecosystem services, will become much more important.

CLIMATE CHANGE ADAPTATION IN FISHERIES AND AQUACULTURE

Adaptation strategies are location and context specific and, hence difficult to model and predict. This section presents some existing and potential strategies for the sector that could reduce vulnerability and increase adaptive capacities towards climate changes, and changes which may combine with them.

Potential adaptation measures in fisheries

A wide range of adaptations is possible, either carried out in anticipation of future effects or in response to impacts once they have occurred. As shown below, some are implemented by public institutions, others by private individuals. In general, responses to direct impacts of extreme events on fisheries infrastructure and communities are likely to be more effective if they are anticipatory, as part of long-term integrated management planning. However, preparation should be commensurate with risk, as excessive protective measures could themselves have negative social and economic impacts.

Table 1. Examples of potential adaptation measures in fisheries

Impact of climate change on fisheries	Potential adaptation measures	Responsibility	Reactive/ anticipatory
Reduced yield	Access higher value markets/shifting targeted species	Public/private	Either
	Increase effort or fishing power*	Private	Either
	Reduce costs to increase efficiency	Private	Either
	Diversify livelihoods	Private	Either
	Exit the fishery	Private	Either
Increased variability of yield	Diversify livelihood portfolio	Private	Either
	Insurance schemes	Public	Anticipatory
Change in distribution of fisheries	Migration of fishing effort/strategies and processing/distribution facilities	Private/public	Either
Reduced profitability	Exit the fishery	Private	Either
Vulnerability of infrastructure and communities to flooding, sea level and surges	New or improved physical defenses	Private/public	Anticipatory
	Managed retreat/accommodation	Private/public	Either
	Rehabilitation and disaster response	Private/public	Reactive
	Integrated coastal management	Public	Anticipatory
	Early warning systems and education	Public/private	Anticipatory
Increased dangers of fishing	Weather warning system	Public	Anticipatory
	Investment in improved vessel stability/safety/communications	Private	Anticipatory
Influx of new fishers	Support for existing local management institutions. Diversify livelihoods.	Public	Either

* May risk exacerbating overexploitation.

As climatic change increases environmental variation, where they have not already done so, fisheries managers will have to move beyond static understandings of managed stocks or populations. Inflexible management approaches may no longer apply and there is a need for implementation of adaptive holistic, integrated and participatory approaches to fisheries management, as required for an ecosystem approach.

Potential adaptation measures in aquaculture

In most cases and for most climate change-related impacts, improved management and better aquaculture practices would be the best and most immediate form of adaptation, providing a sound basis for production which could accommodate possible impacts. An ecosystem approach to aquaculture (EAA) management would be the most effective thematic adaptation measure. As with capture fisheries, responses range from public to private sector and can be reactive or anticipatory.

The aquaculture of extractive species (using nutrients and carbon directly from the environment) such as bivalves and macroalgae, may deserve further attention for their positive ecosystem characteristics and potential food security benefits. Integrating aquaculture with other practices, including agro-aquaculture, multitrophic aquaculture and culture-based fisheries, also offers the possibility of recycling nutrients and using energy and water much more efficiently. These could include fisheries and assist coastal communities in general. Short cycle aquaculture may also be valuable, using new species or strains and new technologies or management practices to fit into seasonal opportunities. Aquaculture could be a useful adaptation option for other sectors, e.g. coastal agriculture under salinization threats, and could also have a role in biofuel production, e.g. algal biomass, using of processing fish discards and by-products.

Most importantly for feed-based aquaculture is its dependence on capture fisheries for fishmeal and oil and its growing competition for terrestrial raw materials. Feeding materials and formulation strategies will be particularly important in maintaining and expanding output while containing costs and energy inputs, and improving resilience to climate change. Adaptations include changing to less carnivorous species, genetic improvements, feed source diversification, better formulation, quality control and management

The Table below summarizes most relevant specific adaptation measures for aquaculture.

Table 2. Climate change related impacts and potential adaptation measures in aquaculture

Climatic change element	Impacts on aquaculture or related function	Adaptive measures
Warming	Raise above optimal range of tolerance of farmed species	Better feeds; more care in handling; selective breeding and genetic improvements for higher temperature tolerance (and other related conditions)
	Increase in growth; higher production	Increase feed input, adjust harvest and market schedules
	Eutrophication and upwelling; mortality of farmed stock	Better planning; sitting, conform to climate change predictions, regular monitoring, emergency procedures
	Increase virulence of dormant pathogens and expansion of new diseases	Better management to reduce stress; biosecurity measures; monitoring to reduce health risks; improved treatments and management strategies; genetic improvements for higher resistance.
	Limitations on fish meal & fish oil supplies/ price	Fishmeal and fish oil replacement; new forms of feed management; genetic improvement for alternative feeds; shift to non-carnivorous species; culture of bivalves and seaweeds wherever possible
Sea level rise and other circulation changes	Salt water intrusion	Shift stenohaline species upstream; introduce marine or euryhaline species in old facilities
	Loss of agricultural land	Provide alternative livelihoods through aquaculture: capacity building and infrastructure
	Reduced catches from coastal fisheries, seedstock disruptions, reduced options for aquaculture feeds; income loss to fishers	Greater use of hatchery seed, protection of nursery habitats, develop/use formulated pellet feeds (higher cost but environmentally less degrading), alternative livelihoods for suppliers
	Increase of harmful algal blooms- HABs	Improve monitoring and early warning systems, change water abstraction points where feasible
Acidification	Impact on calcareous shell formation/ deposition	Adapt production and handling techniques, move production zones,
Water stress and drought conditions	Limitations for freshwater abstraction	Improve efficacy of water usage; encourage non-consumptive water use in aquaculture, e.g. culture based fisheries; encourage development of mariculture where possible
	Water retention period changed (reduced in inland systems, increased in coastal lagoons)	Use different/faster growing fish species; increase efficacy of water sharing with primary users, e.g. irrigation of rice paddy, change species in lagoons
	Availability of wild seed stocks reduced/ period changed	Shift to artificially propagated seed (extra cost), improve seed quality and production efficiency, close the life cycle of more farmed species
Extreme weather events	Destruction of facilities; loss of stock; loss of business; mass scale escape with the potential to impacts on biodiversity	Encourage uptake of individual/cluster insurance; improve siting and design to minimize damage, loss and mass escapes; encourage use of indigenous species to minimize impacts on biodiversity, use non reproducing stock in farming systems

Current biological and system technologies will need to be improved and new technologies developed. Genetic knowledge and management in aquaculture is not as developed as in other husbandries, and will be both a major challenge and an opportunity. Examples include genetic improvement for more efficient feeding and diet specificity, and improved species resistance to higher temperature, lower oxygen and to pathogens. Since aquatic pathogen risks may be exacerbated by climate change, biosecurity and prevention measures may need to change accordingly. Early identification and detection mechanisms may need to be improved, and suitable treatment strategies and products developed.

Potential adaptation measures in post-harvest, distribution and markets

Both capture fisheries and aquaculture feed into diverse and spatially extensive networks of supply and trade to connect production with consumers, adding significant value and generating important levels of employment. To some extent this system can be used to provide an important mediation and buffering function to increasing variability in supply and source location, but direct impacts will also affect its ability to do so. A range of issues and adaptation measures can be considered (Table 3).

Table 3. Climate change-related impacts potential adaptation in post-harvest/distribution

Impact on post harvest, distribution/markets	Potential adaptation measures	Responsibility	Reactive/ Anticipatory
Reduced or more variable yields, supply timing	Wider sourcing of products, changing species, adding value, reducing losses	Private	Either
	Develop more flexible location strategies to access materials	Private/public	Either
	Improving communications and distribution systems	Public/private	Either
	Reduce costs to increase efficiency	Private	Either
	Diversify livelihoods	Private	Either
Temperature, precipitation, other effects on post-harvest processes	Change or improve processes and technologies	Private/public	Either
	Better forecasting, information	Public/private	Either
Vulnerability of infrastructure and communities to extreme events	New or improved physical defenses, accommodation to change	Private/public	Either
	Rehabilitation and disaster response	Private/public	Reactive
	Early warning systems and education	Public/private	Anticipatory
Trade and market shocks	Diversify markets and products	Private/public	Either
	Information services for anticipation of price and market shocks	Public/private	Anticipatory

Management and institutional adaptations

Ecosystem approaches (e.g. to fisheries [EAF] and to aquaculture [EAA]), which incorporate the application of the precautionary approached, embedded within integrated management (IM) across all sectors, have the potential to increase ecosystem and community resilience, providing valuable frameworks for dealing with climate change. These would create flexible management systems, supporting decision-making under uncertainty, and would require that management tools and regulations be rapidly adjusted as necessitated by changed conditions or circumstances. In aquaculture, decisions about resource use, environmental capacity and biosecurity could be developed on a similar basis, and in the post-harvest sector, issues such as food safety and spoilage management could likewise be addressed. Where aquaculture could be used for adaptation in other sectors, planning would be required at appropriate system and management scales, e.g. watersheds, estuaries. These approaches would also provide guidance towards understanding and minimizing perverse incentives leading to overcapacity, overfishing, excessive environmental impact and other harmful practices, as well as defining positive incentives to meet sustainable development goals.

Well defined criteria also need to be set out for sectoral performance to bring climate change threats, risks and potential adaptations within normal management practice. Public and private sector linkages and partnerships will be essential in developing efficient and effective responses. Market demands will be key mechanisms in supporting adaptation, and their impacts on equity amongst suppliers, intermediaries consumers will need to be recognized and applied. Thus certification systems, including sustainability, organic, fair-trade and other criteria will need to be addressed more carefully in the context of climate change, supporting opportunities for more vulnerable groups to engage in economic opportunity. More competitive consequences may also reduce access for poorer people and other vulnerable groups to production, employment and consumption, and adaptation will need to contain strong mechanisms for equity.

CLIMATE CHANGE MITIGATION MEASURES IN FISHERIES AND AQUACULTURE

The primary mitigation route for the sector lies in its energy consumption, through fuel, raw material use and production; though, as with other food sectors, distribution, packaging and other supply chain components will also contribute to the sector's carbon footprint. Net mitigation contributions of fisheries, aquaculture and related supply chain features are small in overall terms but can be improved, and, in some cases, climate change mitigation would be complementary to and reinforce existing efforts to improve fisheries and aquaculture sustainability. However, when implementing such strategies, their possible negative impacts on food security and livelihoods would have to be better understood, justified where relevant, and minimized. There may also be valuable interactions for the sector with respect to environmental services (e.g. maintaining the quality and function of coral reefs, coastal margins, inland watersheds), and potential carbon sequestration and other nutrient management options, but these will need further research and development (R&D).

Greenhouse gas (GHG) impacts of the fisheries sector

Footprint of fisheries operations

Fisheries activities contribute to GHG emissions during capture operations and subsequently during the transport, processing and storage of product. Industrial fisheries have much greater emissions than small-scale fisheries although most boat-based fisheries use motorized vessels and the subsector's fuel:CO_2 emissions ratio has been estimated at around three teragrams of CO_2 per million tonnes of fuel used. Fuel efficiency is defined primarily by motor, propulsion and gear characteristics, but is substantially affected by fisheries management and practice. Any management measures that encourage a "race to fish" create incentives to increase engine power. Overfished stocks at lower densities and smaller individual sizes require vessels to exert more effort, catch greater numbers of individual fish, travel to more distant or deeper grounds and/or fish over a wider area, all of which would increase fuel use per tonne of landings.

Footprint of aquaculture production

Compared to most other animal husbandry practices, aquaculture has a smaller overall CO_2 carbon foot print, as the largest part of production is based on freshwater herbivorous or omnivorous species such as carps, requiring at most small amounts of fertilizer, often organic, and in some cases, low-energy supplementary feeds. However, some species and systems, such as shrimp, salmon and marine carnivores, although only a minor part of total production have high feed energy and/or system energy demands, and consequently very high footprints. Even in these cases, however, the high quality food value (e.g. essential fatty acid content) may need to be recognized.

The global warming potential (GWP) of other gases may also need to be considered. The GWP of methane is estimated to be 23 times that of CO_2, and the terrestrial live stock sector is estimated to account for 37 percent of all human-induced methane emissions. Although aquatic production systems (ricefields, wetland, pond sediments) may also contribute, at so far undefined levels, farmed aquatic organisms do not themselves emit methane and so reducing its total GHG footprint per tonne.

Some developing countries focus aquaculture production on high value but energy intensive species for export. This is very important for livelihoods and food security, but may be more subject to economic risks under climate change scenarios, and will require careful tradeoff assessment for future development. Location and material flows also need to be explored for mitigation potential, as well as a shift or diversification to other species and/or other less energy consuming technologies.

Footprint of post harvest practices

As in all food production sectors, post harvest activities entail stocking, packaging, transport, and post consumption waste, all linked with CO_2 emissions. Of special note are those related to air transport; intercontinental airfreight may emit 8.5 kg CO_2 per kg of fish shipped, about 3.5 times the levels from sea freight, and more than 90 times those from transport of fish consumed within 400 km of source. Product form will also have an important effect, including embodied energy in packaging, and can influence options for maintaining quality and value with respect to transport method. There are important implications for fish trade, upon which many developing nations depend for valuable export earnings. In understanding the carbon footprint of fishery products, defining comparative performance, and areas for potential improvement, emissions need to be traced throughout the entire supply chain, using a full life-cycle analysis (LCA) from harvest to post consumer wastes. The carbon footprint of the sector also needs to be considered in comparison to that of other food production sectors.

Achievable mitigation measures

Mitigation in fisheries production systems

Although a relatively small global contributor, capture fisheries have a responsibility to limit GHG emissions as much as possible. For example, eliminating inefficient fleet structures (e.g. excessive capacity, overfishing), improving fisheries management and reducing post harvest losses/increasing waste recycling will decrease the sectors' CO_2 emissions and improve the aquatic ecosystems' ability to respond (assimilative capacity and ecosystem resilience) to external shocks.

Other technical solutions to reduce fuel use, subject to clear analysis of options and production returns, might include shifting towards static fishing technologies and to more efficient vessels and gears. In some cases, win-win conditions could be identified, where reduced fuel use strategies would link with reducing fishing effort, improving returns to vessels, safeguarding stocks and improving their resilience to climate change. These will also have to be seen in the context of global forces impacting fisheries, such as changing fuel prices and increasing internationalization of fish trade, especially through air freight. Increases in the former will tend to decrease fuel use; while increases in the latter will tend to increase fisheries' contributions to CO_2 emissions. Here too, mitigation decisions need to be seen for the total system.

Mitigation in aquaculture production systems

As with capture fisheries, total GHG contributions are relatively small, but there are equal obligations for reducing impacts. Policies to support climate change mitigation need to be developed, addressing resource access and use, production options and market related measure such as certification, encouraging transparent measures of mitigation standards, comparisons with other food producing, and where appropriate, suitable social inclusion and protection. As with fisheries, a full LCA approach would be required. Key areas for focus would include fishmeal and fishoil, and other feed inputs, water and energy efficiency, especially for small scale producers. Genetic modification technologies could have particular efficiency impacts (e.g. through widening production scope of low-impact aquaculture species, or making agricultural crop materials or waste products usable for growing carnivorous aquatic species) but would require to be evaluated on wider social and political criteria. Technologies and management approaches should be accessible to small and rural farmers.

Mitigation in post-harvest systems

Many of the key elements have already been noted with respect to capture fisheries and aquaculture production. Maximizing the yield and quality, and reducing spoilage will have significant effects, providing the technical measures to do so are themselves efficient. Improved infrastructures and market communication will help to optimize supply to consumption linkages, and measures to increase local availability of aquatic products will reduce overall transport energy requirements, though may need to be balanced against negative impacts on trade and economic opportunities for poorer groups.

Increasing awareness of carbon footprints and their context

The sustainability of fisheries and aquaculture is a priority issue for many fishery stakeholders, and the food security implications are critical development challenges. As concern about global change issues grows, carbon footprint awareness is increasing. Diverse stakeholders including consumers, industry, and governments are becoming more conscious of the scientific, social responsibility, economic and development issues related to the aquatic value chain. There is a critical need for dialogue and collaboration on these issues between industry, government and scientists, as well as for increased awareness among all diverse stakeholders concerning the development choices to be made. The sector will need to engage with such increasing awareness and promote methods and products which meet strategic environmental objectives as well as support social equity and basic access to food.

THE ROLE OF GOVERNANCE IN ADAPTATION AND MITIGATION

There is a critical need for well informed public policy to address mitigation of GHG emissions to limit and minimize impacts of climate change, and the safeguarded benefits in the fisheries sector are an important factor. Sound public policy will also be required for climate change adaptation in order to reduce ecosystem vulnerability, to provide information for planning and stimulating adaptation, and to ensure that adaptation actions do not negatively affect other ecosystem services and the longer term viability of fisheries and aquaculture. The nature and risks of maladaptation – excessive and economically damaging responses to minimal or unsubstantiated risks, or inappropriate responses creating perverse incentives, also need to be better understood. In addition to the good governance principles currently applicable to the sector, agencies responsible for sectoral support and management would support climate change mitigation and adaptation in the sector by:

- building institutional and legal frameworks that consider and respond to climate change threats and uncertainties along with other pressures such as overfishing, pollution and changing hydrological conditions. This requires effective public, private and non-governmental organization (NGO) partnerships, integrating research and management across the sectors and ensuring that regulations limiting access to resources are appropriate to respond to both the threats and benefits of future climate variability;
- moving rapidly towards full implementation of the Code of Conduct for Responsible Fisheries (CCRF), which encompasses the ecosystem approach to fisheries and to aquaculture;
- establishing institutional mechanisms, such as bilateral and multilateral agreements, to enhance mobility of fishing activities within and across national boundaries to respond to changes in resource distribution. This can only be recommended in the context of functional transboundary governance regimes and effective systems to control illegal, unreported and unregulated fishing (IUU), and to ensure transparent and competitive market arrangements are in place;
- enhancing resilience of fishing and aquaculture communities by supporting existing adaptive livelihood strategies and management institutions that are designed to support adaptation to climate change and variability, such as reciprocal access arrangements and conflict resolution mechanisms;
- exploring policies promoting local/regional consumption of aquatic products, versus export-oriented policies, as a form of mitigation, as well shifting or diversifying to other species and/or other less energy-consuming technologies;
- supporting initiatives, such as property rights and other incentive mechanisms, to reduce fishing effort in overexploited fisheries; linking these with the promotion of wider livelihood options, and appropriate financing instruments for change;
- eliminating harmful subsidies and perverse incentives, such as subsidizing fishing fleets under stress (through direct funding, cheaper fuel, or tax cuts), which allow unprofitable fisheries to continue operating and further depress the state of the fish stock(s);
- linking disaster risk management with development planning, especially concerning planning coastal or flood defences; apply “soft engineering” solutions where possible – conservation of natural storm barriers, floodplains, erodible shorelines to manage costs and damage impacts;
- conducting climate-change risk and social impact assessments when evaluating mitigation and adaptation alternatives; including analyses of distributional impacts of such alternatives;

- promoting research on short- and medium-term climate change impacts to support the identification of vulnerability hot spots, the development of adaptation and mitigation strategies, including financing and risk reduction mechanisms, and enabling integrated and broader national planning;
- addressing other issues contributing to vulnerability of the sector's communities, such as access to markets and services, political representation and improved governance; and
- engaging in long-term adaptation planning, including promotion of fisheries and aquaculture related climate issues in Poverty Reduction Strategy Papers and National Adaptation Program of Action, to address longer-term trends or potential large-scale shifts in resources or ecosystems.

CONSTRAINTS TO ADAPTATION AND MAL-ADAPTATIONS

The potential effects of climate change on aquatic organisms and their resources-dependent communities are complex. The general impacts of various scenarios on aquatic systems can be predicted but overall effects on spawning cycle, migration pattern, natural mortality, and community structure of aquatic organisms cannot be predicted. Regime shifts are expected to happen but even gradual changes in climate can provoke unpredictable biological response as ecosystems shift from one state to another. The unpredictability of both the short- and medium-term effects on the ecosystem and the reactions of the communities impacted by these changes is a major constraint to response and adaptation by the fisheries sector to climate change. Conventional decision-making and planning approaches are frequently unreliable under data poor, uncertain and precautionary situations.

In many cases, even basic data, allowing an understanding of the vulnerability of fisheries and aquaculture to climate change, are lacking and, therefore, bases for prioritizing adaptive strategies are constrained. For example, the lack of data for most small island developing states, which would be expected to have very high vulnerability due to reliance on fisheries and low adaptive capacity, has prevented their inclusion in previous vulnerability mapping exercises. While neither vulnerable communities nor data insufficiencies are limited to developing countries, the lack of information is especially acute for them.

Short-term adaptations by fishing communities in response to environmental stresses can lead to their own long-term problems. For example, among the earliest responses to ecosystem change is often to fish harder, deeper, farther from home, in poorer weather, and/or with changes in gear such as decreased mesh sizes. These may increase catches initially but with the long-term consequences of increased and broader impacts to marine systems which further erode their ability to adapt to climate (and other) changes.

For aquaculture, the availability of fish meal and fish oil based feeds will be a major constraint to growth. The shift towards vegetable materials would need to take into account potential scarcities due to water stress as well as competition with food and biofuel demand. Such trade-offs need to be clearly understood at regional and local levels. The use of primary production by herbivorous fish needs to be better quantified and understood at local and regional scales to ensure that their use provides effective adaptation to climate change. The conditions and performance potential of integrated systems also need to be better defined and understood.

Finally, the response of markets to these changes and the implications for prices, economic returns, and sector investment will have major impacts on sectoral performance, employment, food security and longer-term development impact. Information on the drivers of these markets, particularly in highly competitive, internationalized contexts, and the criteria by which products are defined (e.g. production and quality standards, certification) are still limited. The context for which policy changes can accommodate climate change whilst addressing equity issues and delivering acceptable levels of poverty alleviation and food security is even less well understood and needs clear and committed focus.

This Expert Workshop was convened to identify and review the key issues of climate change in relation to fisheries and aquaculture, from the physical changes, the impacts of those on aquatic resources and ecosystems and how these ecological impacts translate into human dimensions of coping and adapting within fisheries and aquaculture. Three comprehensive background documents formed the basis of the technical discussions. The Workshop also evaluated policy options and activities at the international, regional and national levels that can help minimize negative impacts of climate change, improve on mitigation and prevention, and maintain and build adaptive capacity to climate change. The impetus for the Workshop emerged from recommendations of the twenty-seventh session of COFI (2007) as well as to the need to provide inputs into the FAO High-Level Conference on World Food Security: the Challenges of Climate Change and Bioenergy, held in Rome from 3 to 5 June 2008.

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