

THE ECONOMICS OF ADAPTING FISHERIES TO CLIMATE CHANGE

ORGANIZATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, PARIS

WORKSHOP- BUSAN, KOREA

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FOREWARD

Scientific findings indicate that climate change is becoming more apparent and will continue to have a profound effect on the productivity of fisheries and the distribution of fish stocks around the world. However, there is a great deal of uncertainty associated with climate change in a fisheries context, particularly with respect to when it will occur, what kind of changes will take place and the extent of the impact it will have on aquatic ecosystems and fisheries. While global models exist and provide some indication of the magnitude of impacts, much work needs to be done at the local level in terms of understanding how fish stocks will react to changes in the ocean, as well as how ecosystems evolve. From a social and economic point of view, it is clear that the effects of climate change will result in the redistribution of costs and benefits for the fisheries sector and for coastal communities, but *how much, when and to whom* these benefits and costs will flow are less clear. In this regard, there is a need to develop strategies and decision-making models to adapt to climate change under uncertainty for fisheries policy makers, while also taking into account social and economic consequences.

As a complementary exercise to the various other international events on climate change that generally have had a scientific focus, the OECD Committee for Fisheries held a Workshop on the Economics of Adapting Fisheries to Climate Change on 10-11 June 2010 in Busan, Korea, as part of its Programme of Work for 2009-2010. The main objective of the Workshop was to provide a forum for policy makers, economists, biologists, international organisations, the private sector and non-governmental organizations to examine the economic issues, policy challenges and institutional frameworks and responses to adapting to climate change. This publication, the outcome of the Workshop, highlights actions that are needed to respond to climate change: strengthening the global fisheries governance system, a broader use of rights-based management systems, ecosystem protection, industry transformation, ending perverse subsidies and a focus on demand for sustainable seafood. Policy makers will also need to consider how to ensure sustainable aquaculture production as part of adaptation strategies, and how to develop adaptable and flexible fisheries and aquaculture policies within a broader oceans management framework.

The Workshop brought together over 100 participants, ranging from policy makers, fisheries managers, economists and biologists. The two-day Workshop consisted of six sessions which included expert presentations and plenary discussions and focussed on identifying the key economic issues, challenges and possible impacts in relation to climate change and the fisheries; explored adaptation policy measures and options; selected case studies on national adaptation strategies in the fisheries sector; policy issues regarding trans-boundary and high seas stocks as well as climate change adaptation challenges facing developing countries. The Workshop concluded with a panel session on the political economy aspects of developing and implementing climate change adaptation strategies for the fisheries, especially with regard to managing expectations and working collaboratively with stakeholders.

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ACRONYMS (TO BE COMPLETED FOR WHOEL PUBLICATION)

COFI	OECD Committee for Fisheries
COP	UNFCC Conference of the Parties
EEZ	Exclusive Economic Zone
ICES	International Council for the Exploration of the Sea
IOC	
NGO	Non Governmental Organization
OECD	Organization for Economic Cooperation and Development
PACFA	Global Partnerships for Climate, Fisheries and Aquaculture
PICES	The North Pacific Marine Science Organization

CHAIR'S SUMMARY

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Introduction

Recent scientific findings, including the 2007 Intergovernmental Panel on Climate Change report (IPCC, 2007) indicate that the effects of climate change are becoming more evident. Climate change is likely to influence fisheries and aquaculture production in various ways. For capture fisheries, climate change affect fish productivity and distribution through changes in recruitment, growth rates and mortality rates, as well as in the migratory patterns of some stocks. From an economic point of view, these changes will result in losers and winners, between regions or countries as well as within national jurisdictions. With respect to aquaculture production, climate change may necessitate changes in the species composition farmed in some areas depending on tolerability of the species to temperature changes. Other possible impacts of climate change on aquaculture include changes in feed composition and supply as well as changes in the type, scope and extent disease outbreaks in fish farms. For both sectors, relocation of aquaculture production sites, wild harvest landing sites (e.g. ports), and fish processing facilities may be required due to extreme weather events, changing stock distribution and location to markets.

The expected changes in the fisheries and aquaculture sectors caused by climate change will require enhanced adaptability and flexibility in fisheries and aquaculture policies in order to be able to quickly and effectively respond as circumstances evolve. While there will continue to be a great deal of uncertainty associated with the interactions between climate change and fisheries and aquaculture over the next several years, fisheries policy makers should now turn their attention to the development and implementation of climate change adaptation strategies. These strategies must also expressly consider social and economic consequences, and the distribution of impact across time and between stakeholders. More specifically, fisheries policy makers will need to consider the following fundamental questions when developing climate adaptation strategies: What policy options are available? How should decisions be made? When should actions be taken?

Against this backdrop, the OECD Committee for Fisheries (COFI) hosted an international workshop entitled "The Economics of Adapting Fisheries to Climate Change" on 10-11 June, 2010 in Busan, Korea to address these challenges and provide insights to policy makers. Adaptation to climate change was the primary focus of this Workshop in order to allow for a fulsome discussion on this topic. COFI nevertheless recognizes the importance of mitigation strategies as part of a comprehensive response to climate change, and further work in this area is warranted.

The Workshop was designed to provide guidance to fisheries policy makers in terms of when to implement policy changes or develop new policies or approaches to adapt to climate change impacts. Furthermore, it was conceived to allow for an examination of the "tools" in the fisheries manager's "toolbox" in terms of their suitability in the face of climate change, as well as to develop an understanding of the economic, social and environmental information that can underpin decisions on climate change adaptation. The Workshop findings included in the Chair's summary are intended to inform governance considerations that are important to national and international efforts to manage and conserve aquatic resources while adapting to the effects of climate change, as well as other pressures that influence fisheries resources, whether they be natural or man-made. Specifically, the objectives of the Workshop were to:

- Improve the understanding of the interaction between climate change and fisheries and aquaculture from economic, social and institutional perspectives, in light of risk and uncertainty;
- Identify key policy issues that should be taken into consideration when developing fisheries and aquaculture strategies to adapt to climate change;
- Explore the fisheries policy tools that will increase flexibility in adapting to climate change;
- Analyze the possible social and economic consequences of the management strategies to help fisheries decision-making; and,
- Provide fisheries policy makers with insights on developing climate change adaptation strategies and when to make decisions under uncertainty.

Context

As an organization mandated to provide a setting where governments compare policy experiences, seek answers to common problems, identify good practice and coordinate domestic and international policies, the OECD has a particular role to play in the global discussions on climate change and fisheries. Specifically, the OECD's role and expertise regarding economic and policy analysis, coupled with the COFI's analytical work regarding to fisheries economics, management, policy development and governance will assist in shedding light on the economic and institutional aspects of climate change. While the science around climate change is relatively advanced in a number of areas, there are significant gaps in knowledge and particularly a need for informed policy-making, strengthened governance structures, and international cooperation based on sound economic analysis. The OECD Workshop was designed to fill that gap. Figure 1 illustrates the how this Workshop complements and contributes to other international fisheries and climate change conferences.

Figure 1. Role of the OECD COFI in the global discussions on climate change and the fisheries sector



The Workshop agenda was structured to build towards a comprehensive consideration of the subject of fisheries adaptation to climate change, reviewing the status of scientific knowledge, uncertainty, and

fisheries management and governance challenges in order to adapt to climate change. The fisheries management toolbox was also examined, from the perspective of whether or not existing tools are available to develop effective climate change adaptation strategies for the fisheries and aquaculture sectors. In addition, a number of presentations addressed the ecosystem approach, economic implications, and the strategies being employed by various nations to adapt fisheries and aquaculture to the impacts of climate change. There was also an emphasis on adaptation strategies in both developed and developing nations, including an assessment of their respective vulnerability to adapting to climate change impacts. A follow-up session dealt with the political economy of adapting fisheries to climate change with views from the large-scale fishing industry, NGO's and policy makers. Finally, a Panel Session with active involvement of the Workshop participants brought together key findings and insights, with a view to developing key considerations for policy makers.

The growing awareness of the importance of these issues, the shift towards embracing the "Green Growth" paradigm, and the urgency of these matters, offers considerable impetus to move forward, particularly if market forces are harnessed to ensure appropriate reduction in greenhouse gas emissions and more generally in support of green growth and sustainable management practices for aquatic resources. In this context it is important to ensure that the right incentive structures are built.

This Chair's Summary is intended to summarize key insights and major findings of the Workshop and not to repeat all the rich content of the papers presented by speakers. Readers are encouraged to refer to the complete volume of the Workshop Proceedings for further information.

Climate Change and Fisheries Adaptation Issues and Strategies: Current State of Play

The opening presentations examined science, uncertainty, and fisheries management and governance challenges in the context of climate change in order to set the scene for the workshop. Key findings of a recent large-scale ICES, PICES and FAO symposium on the subject held in Sendai, Japan in April 2010 were outlined by a representative of ICES. The Sendai Conference illustrated that while there is a considerable body of science, this information tends to be patchy, with a bias towards developed countries. It also demonstrated that the Ecosystem Approach to Fisheries (EAF), which incorporates multiple and interactive factors, offers the best potential for understanding and responding to climate change impacts on fisheries.

Several participants raised the comparative carbon-related costs of fishing relative to those of other food-related activities such as raising cattle. It was pointed out that many fisheries and aquaculture activities do not contribute significantly to greenhouse gas emissions and that a good case in this regard can be made for such activities compared with more traditional and environmentally costly forms of food production. Panellists concluded that this perspective does not appear to be widely known and may be an important marketing, certification and policy-related point for consideration. Accordingly, there may be benefits in developing and promulgating comparative data of this type for policy-makers.

Workshop participants agreed that clearly, it is very important that fisheries managers and policy makers find effective ways of managing uncertainty and incorporating it in management practices and governance arrangements. In managing both fisheries and those individuals and organizations that conduct fishing, we are dealing with coupled marine socio-ecological systems. One cannot separate the natural science from the social science aspects; in that regard, our systems and processes must take both into account in order to develop effective management and governance structures to deal with the adaptation of

fisheries to climate change impacts. During the workshop, it emerged that uncertainty can be grouped into four categories¹:

- Observational uncertainty, where the current state of system is not known;
- Model uncertainty, in that models are not perfect;
- Process uncertainty where there is a lack of understanding of the system; and,
- Policy uncertainty, where scientific and economic information and advice are inadequately applied.

Workshop participants argued that the ocean has always been variable and that stock collapses are most likely a combination of environmental effects and overexploitation. Climate change is superimposed upon natural variability, with resultant fluctuations in stocks (which may be major or minor in nature) and possible irreversible changes.

A session at the workshop was devoted to the political and economic aspects of developing and implementing fisheries adaptation strategies to climate change, especially regarding stakeholder involvement and expectations. Linked to this is the question of governance and how policy-makers and managers deal with competing interest groups and effect policy change in the face of varying positions. At issue are questions of local, regional, national and international governance, established interests of large and small-scale fishing operations, national and individual self-interest, the effectiveness of governance systems and processes, and how to build consensus to make needed changes for sustainable use of fisheries resources and adapting fisheries to the impacts of climate change. While it was recognized that many fisheries management tools that incorporate uncertainty exists, they may not be effectively applied due to implementation challenges associated with political, social, economic and financial factors.

From a commercial fishing sector perspective, it emerged that changes in fish stock location and abundance presents major challenges, as do the costs of fossil fuels and refrigerants and impacts of incentives to discourage the use of those products. For example, there have been major changes in composition of the New Zealand charter fleet in recent times and major decreases in mid-water landings of a number of species. As fish stocks move and distribution and abundance change, there will be significant issues with respect to access and allocation between affected States and their commercial stakeholders, possibly resulting in situations where national and local community interests may clash.

From a fisheries policy maker's perspective, the need for strengthening already existing good fishery governance practices, including implementing an ecosystem approach to fisheries management, rebuilding fish stocks and applying a participatory approach, was stressed. Lessons can be learned from applying traditional knowledge, involving fishers and building on practices supported by those individuals². While not extensively discussed, the need for adequate fisheries data in light of climate change may be an important consideration given that many fisheries management practices are based on historical, single species data sets. If the ocean changes beyond our historic scientific experience, managers and scientists may have a weakened foundation, also in terms of developing ecosystem strategies.

The experiences of OECD countries as well as non-member economies in identifying climate change impacts on fisheries, developing adaptation strategies and addressing social and economic issues were

¹ . See Chapter ## for additional information on Perry's classification of uncertainty.

² For further information, please refer to the Proceedings of the OECD Workshop on the Economics of Rebuilding Fisheries (OECD 2010).

presented. A number of developed nations are actively anticipating, designing and implementing actions to deal with expected climate change impacts on fisheries. In contrast, developing countries are affected by limited capacity despite the overall importance of the fisheries as a source of food protein. Fisheries on the high seas and those for straddling stocks face unique challenges, as fish move across national boundaries. The following paragraphs identify the state of play at the national and international level, and in some cases illustrates how nations are seeking ways in which to deal with the four types of uncertainty identified earlier.

The EU is currently instituting measures that seek to address both process and policy uncertainty in particular. This is being undertaken through the appointment of a European Commissioner for Climate Action, the establishment of a Commissioner's Group on Climate Change, and an Inter-service Group on Adaptation to Change to explore integration of adaptation policy into policy development. A comprehensive EU climate change adaptation strategy is under development and is intended to harmonize EU fisheries management policies and procedures.

In the United Kingdom, the government is developing an approach for climate change adaptation which considers the impact of increased ocean temperature, sea level rise, ocean acidification and changes in storm intensity and ocean circulation with resultant impacts on fish species distribution and abundance. Adaptation approaches are being designed with the goal of securing sustainable and stable fish biomass, alongside a viable and economically healthy fishery. The core elements of the strategy include building trust between fishers, scientists and government, while also ensuring resilience in marine ecosystems. The incorporation of an ecosystem based approach to marine management is crucial in this regard. The UK also places a strong focus on reducing reliance on government transfers to the sector and instead focussing on market incentives. To this end, the UK government is examining approaches that would allow fishing enterprises greater flexibility and incentives to self-adjust as required, without significant government intervention. Further detail on the UK's fisheries climate change adaptation strategy are provided in a separate chapter in this volume.

In Korea, indications of changing ocean conditions have included the appearance of sub-tropical species and toxic jellyfish, and there have been significant changes in the distribution and abundance of major fish species. In response, Korea has instituted the comprehensive Marine and Fisheries Policy in 2007 and the National Action Plan for Climate Change in 2009. These two policies incorporate climate change initiatives, including strengthening resource management for emerging warm water species while taking advantage of new harvest opportunities, developing farming technologies for new species (e.g. tuna), and creating marine parks to protect fish habitat and spawning grounds.

Similarly, Chinese Taipei has experienced significant changes in distribution and abundance of fish stocks in recent years. There have been declines in key fisheries linked to climate change effects, with the resultant impacts on fishers and the fishing industry. Typhoon-induced floods have had major impacts on the aquaculture industry through facilities damage and escapes of cultured fish. Major reductions in fisheries catches are projected to occur. Adaptation strategies are under development in Chinese Taipei that are intended to design specific adaptation measures to supplement current management practices.

The workshop also identified the divergence in approaches and highlighted the varying levels of capacity between developing and developed countries in adapting to climate change. In many developing countries, marine and freshwater fisheries are an important source of protein and national food security, as well as crucial to the livelihoods of parts of the population. Some are land-locked countries with a dependence on freshwater fisheries and aquaculture. Accordingly, as global climate change impacts intensify and affect freshwater availability and food security issues, impacts on fisheries and aquaculture may be severe.

It emerged that developing nations appear to be the most vulnerable to the effects of climate change on fisheries, and many lack the capacity to adapt and cope with these impacts. In this vein, a global study on the effects of climate change conducted by the UK QUEST project explored the vulnerability of countries was presented. This study used an indicator-based approach based on exposure, sensitivity and adaptive capacity of the societies and noted that vulnerabilities were especially high in developing countries. African countries, former Soviet countries and landlocked countries were identified as most vulnerable.

As a way forward, a number of adaptation strategies to restore and sustain the food production potential of the coastal fisheries of Pacific Island nations were proposed: applying an EAF, increasing access to tuna for subsistence fishers with low-cost, inshore Aggregating Fish Devices, storing and distributing tuna and by-catch from industrial fleets to urban areas; and developing pond aquaculture. The debate about sharing experiences and building capacity among nations was illustrated by the example of “The Blue Economy Initiative” of the Korea 2012 Yeosu EXPO. This program is intended to institute a capacity-building program where resources will be devoted to developing countries in order to deal with problems in the field of marine and fishery affairs, including climate change impacts.

The Workshop also addressed management of fisheries and aquaculture in the ocean area beyond national jurisdictions in a world where climate is changing. Participants generally agreed that major steps have been made in addressing international agreements and regulatory arrangements for high seas fisheries through initiatives such as the UN Fish Stocks Agreement, FAO Compliance Agreement, and the FAO international Plan of Action. However, given the size of the ocean and limited enforcement capacity, it was concluded that illegal activities are largely state failures that result from either a lack of capacity or lack of will. While the international legal framework to effectively manage fish stocks and adapt to climate change exists, further work on implementation (e.g. enforcement) is required.

Changes in fish distribution resulting from variations in ocean conditions will likely affect fish stock sharing arrangements between countries regarding straddling stocks, creating a need to develop incentives for those countries that may receive smaller shares as a way to ensure conservation. However, one provocative comment raised during the discussions was that future changes in fish abundance on account of climate change may not be as dramatic as what was seen in the 70s and 80s as a result of overexploitation. As such, we may be able to draw on past fisheries management measures that were effective in rebuilding or managing depleted stocks.

Key Messages for Fisheries Policy Makers

Climate change will impact fish species in uncertain ways relative to their current range of distribution or historical patterns, and some species within an ecosystem may shift in one direction (e.g. north), while others move in the opposite direction (e.g. south). This may result in changes in ecosystem structures themselves, as species that have traditionally cohabited within certain geographical ranges may move apart, altering predator/prey interactions for example. Resilient fisheries management regimes are required in order to provide a buffer against this uncertainty.

At issue is the effectiveness of fisheries organizations and existing governance structures and their ability to ensure conservation and sustainability while being adequately flexible so as to deal with change. It is clear, that climate change impacts, in association with natural variation and the various factors that affect fish stocks and the ecosystems they inhabit, will add uncertainty to fisheries management and pose a challenge to our efforts to conduct sustainable fisheries, feed a growing global population, and put in place effective international fisheries organizations and arrangements. Fostering initiatives to address key gaps in natural and social scientific knowledge associated with fisheries adaptation to climate change including specific impacts on major target species, shifts in ecosystem dynamics related to climate change, public

awareness and decision-making and incentives to policy change and good fisheries management governance arrangements and practices will be essential. Based on the discussions and findings of the workshop, this section outlines the main messages to be considered by fisheries policy makers in adapting to climate change challenges in the fisheries and aquaculture sector.

i) The fisheries toolbox to adapt to climate change already exists, but stronger and more flexible governance frameworks are needed.

The consensus of the Workshop is that an effective array of management tools exist to allow us to adapt to the impacts of climate change on fisheries, although governance itself appears to be the weak link. It was highlighted that evolving, responsible, and resilient fisheries management establish a contextual and participatory governance framework characterized by flexible and adaptive operational and strategic fisheries decision making³. Often, emphasis is placed on examining the causes of stock collapses, but rarely do we look at and capitalize on the lessons learned from stock recovery. However, it was agreed that it is possible to strengthen fisheries management systems in ways that make them more capable to address climate change by incorporating a consciously adaptive management framework to deal specifically with climate change emphasize elements of the toolbox that explicitly consider uncertainty.

In this regard, there is a need to avoid “institutional mal-adaptation” which refers to a governance structure that assumes the ecosystem is static, rather than a structure that recognizes that for example, fish distribution will evolve over time. For instance, in cases where species managed under a quota system move between pre-determined zones and the fishers cannot “follow the fish” to an area where they do not hold quota is evidently problematic. Designing an enabling framework and developing markets for trading domestic and international quotas were raised as options in this regard. Another case in point refers to marine protected areas; such geographically based tools require some inherently flexibility so as not to be rendered redundant as species migrate to more suitable climates. Participants discussed that an important role for governments include identifying and removing institutional barriers, periodically reviewing protection measures to see if they are still applicable and ensuring that they do not dilute incentives for fishers to adapt to climate change, as well as addressing ongoing concerns such as discards, while also building trust between fishers, scientists and governments.

Furthermore, “coping strategies” will need to be developed as aquatic conditions change and the ecosystem responds. In the short term, this may include tuning fishing intensity, gears, times, areas, target species, etc. and using the appropriate methods in the fisheries management toolbox. In the longer term, adapting to climate uncertainty will require political reform leading to effective governance arrangements, and the will and capacity to enforce the required management actions. In this regard, marine spatial planning (or aquatic spatial planning) and integrated ocean management is an important element in developing strategies to respond and adapt to fisheries climate change.

ii) The economic effects of climate change will depend on specific conditions of a fishery or coastal community and need to be taken into account in developing adaptation strategies.

Economic effects are influenced by a number of factors, including value of catch (e.g. productivity, size, species distribution, markets, etc), costs of production (e.g. new investment and energy consumption), employment, community economies (reach of the market for seafood and their flexibility in responding to changes in supply and prices), redistribution of benefits and costs among stakeholders, and long-term profitability and ability to account for a range of possibilities. Economic effects depend on the context of a situation and may be positive or negative. Economic vulnerability of a business or an individual is related

³ See the paper written by Dan Lane in Chapter ## for more detail.

to the level of exposure to change, response capability, and level of dependence on the fish species or group of species in question.

Economic effects can be positive, negative or neutral depending on circumstances, with vulnerability to economic effects affected by level of exposure to change, sensitivity to change, level of fishery dependence and response capacity. In addition, there is an inherent contradiction between stability and flexibility and that managing portfolios of fisheries (e.g. multi species approach) may promote more resilience for fisheries and fishing enterprises than managing single stock managing individual fishery units.

iii) Involve stakeholders and communicate with them in designing and implementing climate change adaptation strategies.

The need to consider the human dimension of fisheries management and the need for stakeholder engagement, including literacy and capacity, was also emphasized. In particular, the need to engage the public (the fisheries resource users) as well as the broader set of stakeholders in order to anticipate social and economic impacts, explore options, make the necessary choices and implement effective policies was highlighted. Inclusion of local and traditional knowledge is an important element of this approach. Effective engagement will facilitate the necessary social, economic and political policy changes required to adapt. Failure to do this may cause the often competitive and sometimes antagonistic relationships between competing interests to persist and frustrate effective change and governance. Accordingly, there is a need to better communicate with a broader set of stakeholders and the public with respect to fisheries, global food and water security issues, and the impact of climate change in order to facilitate awareness, establish priorities and develop the needed political and societal support for adaptation.

There is a need to think about how to communicate and implement overarching good governance principles of fisheries management and incorporate climate change impacts while doing that. In this way, the focus would be less on climate change per se, but would be considered as part of the complexity and uncertainty to be addressed as part of fisheries management. An important part of building understandings and effecting policy change is the need to inform people about anticipated impacts so that choices can be made. This will require more engagement of economists and social scientists to assist the public in gaining understanding and in facilitating change based on human behavioural patterns. Understanding the natural science and the biology and oceanographic implications will not be sufficient to achieve the necessary changes. The social-ecological relationships will need to be addressed as well.

iv) New arrangements for international fisheries management to deal with stock migration and conserve the stocks are required

A continued focus on efforts and initiatives to elucidate, foster and develop adaptive, flexible international arrangements, agreements, organizations, and cooperation to address the fisheries climate change adaptation challenge and to promote effective stewardship, conservation and good governance of aquatic resources is essential. The changing distribution of fish stocks and altered abundance in the face of climate change will require a renewed focus on developing and/or adapting international fisheries agreements that address fish stock migration between EEZs, and treaties governing the distribution of shared stocks amongst countries. Strengthening regional fisheries management organizations will also be key to managing fish stocks as they migrate on the high seas, with the added urgency posed by stress on the stocks due to exploitation as well as climate change impacts.

Some changes in species abundance, distribution or ecosystem composition may be irreversible; these shifts will put international arrangements and treaties under stress. As a result, innovative incentive structures and adaptation strategies will need to be considered, including side payments to countries that would offset reductions in their fish catches; greater flexibility regarding fishing in adjacent zones and in

foreign EEZs; the advent of new technology; creating and accessing new markets or introducing new products; and, increased flexibility to deal with supply changes in relation to market demand.

v) Sustainable aquaculture production, the Ecosystem Approach to Fisheries management and strong science are core elements of a fisheries adaptation strategy

Sustainable aquaculture production may be one solution to supplement stagnating/declining capture fisheries or those affected by climate change. Sustainable aquaculture has the potential to help address global food security challenges and may be particularly important for developing countries where fish forms a very important component of the diet. Aquaculture may offer flexibility in dealing with challenges associated with climate change such as water scarcity, storms, temperature, choice of adaptive species, etc. Technological developments to increase the ability to adapt fish cages and installations to prevent storm damage, techniques for dealing with temperature stress, breeding technology innovations, genetic engineering, improved food sourcing away from reliance on fish meal, and reduced antibiotic use would be key elements of ensuring sustainable aquaculture production. A simpler governance model compared to wild fisheries, in which property rights for aquaculture sites and stocks are clearly assigned, was also considered a benefit.

There was strong consensus that adoption and implementation of the ecosystem approach is a very important strategy as it is only this approach which can incorporate all elements which are necessary to deal with the complexities of natural systems and the impact of climate change. This however, is a major task and often ecosystems are not well understood and our ability to manage fisheries stocks on a multi-species basis is not well developed.

While there is considerable scientific work being done, the global view on climate change impacts on fisheries is patchy and not fully understood. There is a need for more comprehensive science, particularly with respect to fisheries of developing countries, and a focus on key stocks and areas of concern which will vary geographically in sensitivity to climate change. Aligning global estimates of climate change to the local scale and accordingly downscaling predictions to the local level remains a challenge and must be addressed as is assigning a priority to further elucidating the biological, social and economic impacts of climate change on fisheries and aquaculture.

vi) Developing countries are especially vulnerable to climate change, calling for knowledge transfers and capacity building

For developing countries, there is an urgent need for anticipating and understanding the expected impacts, developing adaptive capacity, particularly for knowledge transfer, capacity building, and effective technology transfer from developed countries. Furthermore, small developing countries with coastal or artisanal fisheries may be significantly impacted by distant water fishing nation activities which may change with climate change influences. Considerable research and development efforts are needed in this area to ensure that other human activities and uses (e.g. urbanization, population growth, and agriculture) are not negatively effecting water quality, fisheries productivity or aquaculture potential. In short, a focus on the specific problems of developing nations and their lack of capacity to deal with fisheries climate change adaptation and need for assistance from developed countries is required.

Future research and consideration

This Workshop covered a vast and complex topic of global proportions with strong implications for the fisheries and the aquaculture sector, and with major elements of an economic and social nature. Global water security issues and their impact on fisheries and aquaculture, including in the freshwater environment, are major challenges. Effective water use and water conservation initiatives, anticipating and coping with storms, floods, drought, snow-pack depletion, coastal sea level changes, and impacts on

freshwater ecosystem integrity are topics for important research and policy development. These issues have both a natural science and a social science dimension in terms of choices that must be made with respect to global water security issues, including those related to the fisheries sector. In this regard, future work on climate change and the fisheries should also consider the following aspects:

- **Mitigation:** There is a major difference in the costs and benefits of adaptation and mitigation activities respectively. The costs and benefits of *adaptation* are more likely to be local in nature, and can thus strain countries with limited capacity and resources to implement adaptation measures. In contrast, the costs of *mitigation* are more likely to be local, while the benefits are often diffuse and experienced on a global scale. Research to assess the various approaches and strategies regarding mitigation of the effects of climate change (e.g. carbon sequestration in the oceans; increasing fuel efficiency for fishing vessels) for fisheries and aquaculture is required. In addition, the scale and scope of socio-economic sensitivities of fisheries to climate change, including the associated fishing communities, may be assessed in terms of their resilience to respond to the effects of climate change. Such work would help identify if the fishery can adjust autonomously or whether targeted transitional policies (e.g. additional capacity building or economic development) are needed.
- **Integrated marine management** that takes a comprehensive approach to examining the cumulative impacts of the various human activities in the ocean is required. This may include shipping, oil exploration, fishing, tourism etc. Holistic management plans may be based on an assessment of the impacts on the marine environment of human activities and the interactions between them. Elaboration of the necessary elements of a governance structure that adopts such an integrated approach would enable strong institutional frameworks within which to deal with climate change.
- **Freshwater fisheries:** There is a need for more emphasis on climate change impacts on freshwater fisheries which will affect many of the most vulnerable countries with a strong dependence of fisheries for food security. The ocean has always been a highly variable ecosystem and variation in abundance and distribution of fish stocks has always challenged fisheries managers, with considerable uncertainty present which must be accounted for. In many locations around the world, changes in fisheries related to phenomena in the ocean are being observed, particularly changes in fish distribution and abundance. Changes are also happening in freshwater water bodies, and these must equally be considered in the development of climate change mitigation and adaptation strategies.