FAO Fisheries and Aquaculture Circular No. 1066 RNE/FIPI/C1066 (En)
ISSN 2070-6065

ADAPTING TO CLIMATE CHANGE: THE ECOSYSTEM APPROACH TO FISHERIES AND AQUACULTURE IN THE NEAR EAST AND NORTH AFRICA REGION

Workshop Proceedings: FAO/WorldFish Workshop, Abbassa, Egypt 10–12 November 2009

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2011

ISBN 978-92-5-106822-9

PREPARATION OF THIS DOCUMENT

This project was initiated by FAO in order to address how the ecosystem approach to fisheries and aquaculture can be used to address the impacts of climate change to fisheries and aquaculture in the Near East and North Africa Region (RNEA).

A workshop was held in December 2009 with Member Countries and with the purpose of:

- developing awareness among Member Countries and stakeholders of the need for the ecosystem approach to fisheries and aquaculture and of its implementation on the basis of the best available knowledge and information;
- strengthening capacity among FAO RNEA Member Countries and the Regional Commission for Fisheries (RECOFI) constituents for planning and implementation of the ecosystem approach to fisheries and aquaculture;
- improving knowledge and awareness of the current and future implications of climate change for fisheries and aquaculture;
- providing guidance on best practices for adaptive planning and management, and adaptive strategies in general, for coping with climate change.

The document provides suggestions and recommendations made by the experts regarding the adoption of the ecosystem approach to fisheries and aquaculture that are considered to be important in helping adapt to climate change in the region. It also contains five technical review papers (climate change, the ecosystem-based approach to fisheries, the ecosystem-based approach to aquaculture, climate change and fisheries, and climate change and aquaculture) and four subregional reviews (Mauritania/Morocco, Mediterranean, Red Sea and Gulf of Aden, Persian Gulf and Sea of Oman) prepared as background material to the workshop. The report was prepared by the workshop secretariat.

Curtis, L.; Beveridge, M.C.M.; el-Gamal, A.R.; Mannini, P. (eds).
Adapting to climate change: the Ecosystem Approach to Fisheries and Aquaculture in the Near East and North Africa Region – Workshop Proceedings.
FAO Fisheries and Aquaculture Circular. No. 1066. Rome, FAO. 2011. 130p.

ABSTRACT

A workshop was held in December 2009 with Member Countries and with the purpose of: developing awareness among Member Countries and stakeholders of the need for the ecosystem approach to fisheries and aquaculture and of its implementation on the basis of the best available knowledge and information; strengthening capacity among the Near East and North Africa countries for planning and implementation of the ecosystem approach to fisheries and aquaculture; improving knowledge and awareness of the current and future implications of climate change for fisheries and aquaculture; and providing guidance on best practices for adaptive planning and management, and adaptive strategies in general, for coping with climate change.

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A special thank you to all of those who provided support at the Abbassa Research Facility and the FAO Cairo office, as well as the support of the Government of Egypt.

Finally, the authors would like to thank FAO and WorldFish Center for providing support for this workshop.

ABBREVIATIONS AND ACRONYMS

AOGCM	Atmosphere–Ocean General Circulation Model
AR	Assessment Report
BCLME	Benguela Current Large Marine Ecosystem
BMP	better management practice
CBD	Convention on Biological Diversity
CCLMRAR	Commission for the Conservation of Living Marine Resources of the Antarctic Region
Code	Code of Conduct for Responsible Fisheries
COFI	Committee on Fisheries (FAO)
CO_2	carbon dioxide
CRU	Climatic Research Unit
DMN	Direction de la Météorologie Nationale (Morocco)
DPM	Département des Pèches Maritimes (Morocco)
DRM	disaster risk management
EA	ecosystem approach
EAA	ecosystem approach to aquaculture
EAF	ecosystem approach to fisheries
EAM	ecosystem approach to management
EBFM	ecosystem-based fisheries management
EEZ	economic exclusive zone
EIA	environmental impact assessment
ESD	ecologically sustainable development
EU	European Union
GDP	gross domestic product
GEF	Global Environment Facility
GFCM	General Fisheries Commission for the Mediterranean
GHCN	Global Historical Climatology Network
GHG	greenhouse gas
GIS	geographic information system
GRT	gross register tonnage
GWP	global warming potential
HCEFLD	High Commissioner for Water, Forests and Combating Desertification (Morocco)
HUFA	highly unsaturated fatty acids
IAA	Integrated Agriculture Aquaculture
IFRO	Iranian Fisheries Research Organisation
IM	integrated management
IMTA	integrated multitrophic aquaculture
INRH	Institut National de Recherche Halieutique, Morocco
INSTM	Institut National des Sciences et Technologies de la Mer, Tunisia
IPCC	Intergovernmental Panel on Climate Change
LCA	life cycle analysis
LME	large marine ecosystem
MCS	monitoring, control and surveillance
MDG	Millennium Development Goal
MEA	Millennium Ecosystem Assessment
MPA	marine protected area
NAO	North Atlantic Oscillation
NCDC	National Climatic Data Center (United States Department of Commerce)
NGO	non-governmental organization
NIVA	Norwegian Institute for Water Research
OIE	World Organization for Animal Health
ONP	Office Nationale des Pèches (Morocco)

OU	operating unit
PaCFA	Global Partnership Climate, Fisheries and Aquaculture
PERSGA	Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden
PPP	Purchasing Power Parity
RECOFI	Regional Commission for Fisheries
RESGA	Red Sea and Gulf of Aden
RNEA	Near East and North Africa Region (FAO)
SAH	Sahara
SEM	Southern Europe and Mediterranean
SLA	sustainable livelihoods approach
SRES	Special Report on Emissions Scenarios
SST	sea surface temperature
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
UN-REDD	The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
VMS	vessel monitoring system
WTO	World Trade Organization

EXECUTIVE SUMMARY

The FAO/WorldFish workshop entitled "Adapting to Climate Change: the Ecosystem Approach to Fisheries and Aquaculture in the Near East and North Africa Region" took place in November 2009 to identify and address the impacts created by climate change in the Near East and North Africa Region (RNEA), and how the ecosystem approach (EA) can be utilized for the management and adaptation of fisheries and aquaculture in the face of these impacts.

The impacts of climate change will affect and change the industries of fisheries and aquaculture, and therefore affect food security and livelihoods in the Region. The predicted impacts are not standard or consistent across the Region; one country's loss may be another country's gain. Regardless of the specific losses and gains, food security, the stability of supply, availability, access and utilization will all be affected. Vulnerability arises from the combined effect of these impacts, the importance of fisheries and aquaculture with respect to food security and livelihoods, as well as a limited capacity for these industries to adapt.

The ecosystem approach to fisheries (EAF) and the ecosystem approach to aquaculture (EAA) are not new strategies. Rather, they pull together existing instruments and agreements, stressing holistic, integrated and participatory processes. The key features of the EAF/EAA are maintaining ecosystem integrity while improving human well-being and equity and promoting an enabling governance. Three objectives that must be at the core of the EA are: ensuring ecological well-being, ensuring human well-being, and ensuring the ability to achieve (governance and external factors).

The subregions of the Mediterranean, Atlantic (Morocco/Mauritania), Red Sea and Gulf of Aden, and the area covered by RECOFI have different levels of fisheries and aquaculture development, as well as varying institutional, financial, willingness and human capacities for the implementation of EA strategies with respect to climate change adaptation. The purpose of this workshop was to develop awareness among workshop participants on the impacts of climate change and on how the EAF/EAA can be used, not only for adaptation but also for mitigation. The outcomes of this workshop demonstrated that there is a capacity and a will by Member Countries to address climate change with respect to fisheries and aquaculture, but there remain important challenges that must be addressed in order to prepare these sectors adequately for the impacts of climate change.

1. WORKSHOP

1.1 Introduction

1.1.1 Opening speech on behalf of the Central Laboratory for Aquaculture Research in Egypt

The workshop began with a speech delivered by Dr Gamal el-Naggar, Director of the Central Laboratory for Aquaculture Research in Egypt.

Climate change has moved to the forefront of the world's environmental agenda and rightly so. Scientific evidence that the activities of mankind have altered global climate to the extent that our very survival appears to be in jeopardy is incontrovertible. It must be emphasized that global climate change has been a matter of grave concern within the scientific community for some time and has been the subject of a large number of scientific investigations. The vast body of scientific knowledge that has been accumulated over the past 50 years is notable for its high level of agreement, and has been recently reviewed by a United Nations established Intergovernmental Panel on Climate Change (IPCC).

The IPCC projects that atmospheric temperatures will rise by 1.8–4.0 ^{o}C globally by 2100. This warming will be accompanied by rising sea temperatures, changing sea levels, increasing ocean acidification, altered rainfall patterns and river flows, and higher incidence of extreme weather events. The biological components of our environment have evolved in harmony with the physical and climatic surroundings. The presence, characteristics, structure and behaviour of both individual organisms and co-assemblages, or communities, of organisms are largely determined by climate. The ability of natural communities to adapt to changing climate and nature of community change is of utmost importance to the survival of man.

Approximately 520 million people (8 percent of the world's population) depend on fisheries and aquaculture as a principal source of protein, income or family stability. With over 400 million of the world's poorest depending on fish for food, it is essential that climate proofing fisheries and aquaculture is high on the agenda for climate change. Many fishery-dependent communities and aquaculture operations are in regions highly exposed to climate change. It is becoming increasingly clear that the impact of climate change will disproportionately hurt the poorest communities and those in small inland states.

Climate change will impact aquatic ecosystems and alter the distribution and production of fish. Fish migration routes, spawning and feeding grounds, and fishing seasons are likely to change and the impacts on fishing communities and harvests are uncertain. Vulnerability arises from the combined effect of predicted warming, the relative importance of fisheries to national economies and diets and limited capacities to adapt.
Quality research is essential for climate-proofing our future and fish are a vital part of the future. High-quality research involves resource users, builds strong partnerships and harnesses political support, it is crucial for making fisheries and aquaculture systems more resilient to global climate change. Decisions informed by high-quality research will be key to securing a better future for the poor who depend on fisheries and aquaculture.

The task ahead of us is both urgent and complex. The consequence of non-action is potentially the end of civilization, as we know it, on this planet. These are some of the questions that you are invited to explore and discuss.

i. What are the threats?
ii. What can we do to alleviate these threats?
iii. What can we do to aid the survival of our civilization?
iv. Can humankind adapt to the changes in environment caused by global climate change?

1.1.2 Opening address on behalf of FAO Regional Office for the Near East and North Africa

This opening address was delivered by Dr Piero Mannini, Senior Fishery Officer on behalf of Dr Abdessalam Ould Ahmed, acting Assistant Director-General and Regional Representative for the Near East and North Africa FAO Regional Office for the Near East and North Africa. On behalf of the Food and Agriculture Organization of the United Nations, I wish to welcome you to the WorldFish Center Field Research Station in Abbassa, Egypt, and to participate in the FAO/WorldFish regional workshop Adapting to Climate Change: the Ecosystem Approach to Fisheries and Aquaculture in the Near East and North Africa Region.

The region covered by the FAO Regional Office for the Near East and North Africa encompasses a wide and dispersed geographical area of different marine and freshwater ecosystems and fisheries with different characteristics and complexity. This FAO Region extends from the East Central Atlantic Ocean on the west, to the Indian Ocean and Arabian Sea in the east. It includes regional seas (such as the southern and eastern Mediterranean Sea, Red Sea, Persian Gulf and Sea of Oman), national and regional rivers, lakes and other bodies of water.

The landing of marine capture fisheries in the region has been growing since the 1950s, from less than 500 000 tonnes to about 3 000 000 tonnes in 2006. Aquaculture production, which was almost non-existent till the 1980s, shows a significant increase that has been particularly remarkable from the late 1990s. Currently, its total production is more than 500 000 tonnes. Despite this positive trend of the total landing from capture fisheries, many of the most vulnerable species are overexploited and changes in ecosystem structure and fishery productivity are reported in some areas of the region. Moreover, fisheries in the region rely upon ecosystem services and goods that are often shared with other coastal countries. To ensure the responsible management and sustainable exploitation of the fisheries resources, the strengthening of regional cooperation is needed.

In most countries, lacking complete, up-to-date surveys and accurate and timely data on fish landings, it is difficult to estimate the state of stocks. Inland capture fisheries stocks are also under threat of declining catches, mostly due to overfishing, unmonitored stocks and exploitation, environmental degradation, plus poor statistical gathering to monitor status of stocks.

With the uncertain potential for increasing fish supply from marine and inland capture fisheries, the future supply of fish in the Region will most likely depend on aquaculture. However, there are environmental, technical, economic and legal constraints of varying degrees that need to be overcome in many countries of the Region if aquaculture is to develop.

The attainment of the goal of sustainable development and utilization is being constantly threatened by a multitude of factors internal and external to the fisheries and aquaculture sector. 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 climatic changes. Coastal populations, 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.

Climate change is modifying the distribution of marine and freshwater species. In general, species are being displaced toward the poles and are experiencing changes in the size and productivity of their habitats and seasonality of biological processes. Sea-level rise, glacier melting, ocean acidification and changes in precipitation, groundwater and river flows will significantly affect many ecosystems, including coral reefs, wetlands, rivers, lakes and estuaries.

Climate change will have potentially significant impacts on the four dimensions of food security: availability of aquatic foods will vary through changes in habitats, stocks and species distribution; stability of supply will be impacted by changes in seasonality, increased variance in ecosystem productivity and increased supply variability and risks; access to aquatic foods will be affected by changes in livelihoods and catching or farming opportunities; utilization of aquatic products will also be impacted and, for example, some societies and communities will need to adjust to species not traditionally consumed.

Not all climate change impacts will necessarily be negative. Redistribution of fish stocks may mean that one country's loss is another's gain. The world's fishing fleet is mobile, markets for many fishery products are global and management systems such as access agreements and internationally traded quotas increasingly facilitate adaptation. In this dynamic context, countries and firms with greater resources and adaptive capacity will gain most from positive changes. Poorer countries and people might still be vulnerable to missing out on benefits of positive change.

It has been increasingly recognized that reducing the vulnerability of fishing communities as a whole can help address poverty and resource degradation, and enhance adaptive capacity to a range of shocks, including those resulting from climate variability and extreme events. The need for adaptation is a feature of all livelihoods dependent on natural resource utilization but projected climate change poses multiple additional risks to fishery dependent communities. Options to increase resilience and adaptability include the adoption, as standard practice, of adaptive and precautionary management within an ecosystem approach to fisheries (EAF) and an ecosystem approach to aquaculture (EAA).

The FAO EAF has been adopted by the Committee on Fisheries (COFI) as the most appropriate management framework and is explicitly indicated as the target framework by the World Summit on Sustainable Development (2002). The EAF principles are the same as those of the Code of Conduct for Responsible Fisheries (the Code) and provide a framework for implementing these in a more holistic and structured way. The EAF and EAA apply the precautionary approach, are embedded within integrated management across all sectors, have the potential to increase ecosystem and community resilience, and are valuable frameworks for dealing with climate change.

The EAF and EAA are comprehensive approaches to fisheries management and aquaculture development that envisage participatory approaches and consideration of a broader set of issues that include the broader impacts of fisheries on the ecosystem in addition to those on target species. Furthermore, social, economic and governance considerations that are important components of sustainability are also taken into consideration. The EAF/EAA recognizes that decisions have to be made with the information available, that it is not possible to wait to have a complete understanding of all the processes and that decisions made must deal with trade-offs between stakeholders as well as between the various components of sustainability.

In line with the indication given at the COFI 2007 and 2009 sessions, and to take action with respect for the concerns expressed at the 29th Regional Conference for the Near East (2008) on the impact of climate change, FAO in partnership with the WorldFish Center has conceived the present regional multidisciplinary workshop on Adapting to Climate Change: the Ecosystem Approach to Fisheries and Aquaculture in the Near East and North Africa Region.

The objectives of the workshop are to: 1) develop awareness among Member Countries and stakeholders of the need for an ecosystem approach to fisheries and aquaculture and of its implementation on the basis of the best available knowledge and information; 2) strengthen capacity among FAO Member Countries for planning and implementation of the Ecosystem Approach to Fisheries and Aquaculture; 3) improve knowledge and awareness of the current and future implications of climate change for fisheries and aquaculture; and 4) provide guidance on best practices for adaptive planning and management, and adaptive strategies in general, for coping with climate change.

Distinguished participants and colleagues, 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: national, regional and international.

1.2 Background presentations

The workshop was divided into two main activities: background presentations, and working group sessions. The presentations were given to summarize the main issues from the background papers, written on topics relevant to the workshop, and were designed to facilitate a knowledge base for the working group discussions that would follow. These presentations were divided into background information of a twofold nature: technical summaries by experts from the WorldFish Center and FAO; and subregional reviews by fisheries and aquaculture experts from the bodies of water covered by the Regional Commission for Fisheries (referred to as the RECOFI[1] region), the Red Sea and Gulf of Aden (RESGA), the Atlantic and the Mediterranean subregions. Below is a brief summary of the background papers, which constitute Sections 2 and 3.

1.2.1 Technical papers

Climate change in the Near East and North Africa Region, by H. Kanamaru (FAO)
The African continental surface temperature has risen since 1900, and it is predicted that the global surface temperature will continue to rise. This is also predicted specifically for the region of the Near East and North Africa. This is combined with predictions of decreased rainfall in the region, up to a decrease of 20 percent in the North Africa region. The estimates for an increased frequency and degree in extreme weather events globally are predicted as between very likely and virtually certain to occur. In warm climates, agricultural yields are expected to decrease. Sea-level has been rising and will create both physical and socio-economic losses. While the global impacts of climate change are clear, regional and subregional climate change and its effects on natural and human environments are difficult to determine and are being recognized only recently. This is due to greater natural climate variability at regional scales, local non-climate factors and limited spatial coverage and short time scales of many studies.

Plenary discussion
Regarding weather and precipitation, it is difficult to see regional trends based on country or individual weather stations, as stations can be heavily influenced by topography. It is necessary to look at the bigger picture for trends in order to understand where there will be increases or decreases in precipitation.

While there is projected to be a decrease in precipitation in North Africa, what impacts will the increase in Central African precipitation cause, particularly with regard to the Nile River?
The increase may bring positive impacts on the flow of the Nile River; however, it is difficult to predict how the water will be used, or where it will be lost as a result of the change.

The ecosystem approach to aquaculture: challenges and opportunities under climate change scenarios, by D. Soto (FAO) and P. White (NIVA)
Aquaculture has been increasing in its share of global food-fish supply since 1970, and could potentially contribute 50 percent by 2011. As aquaculture, unlike capture fisheries, is a production process, a systems consideration of how much is coming in and how much is going out is required early in the planning process. The EAA is a strategy that integrates aquaculture within the wider ecosystem, strengthening the resilience of interlinked socio-ecological systems. Three objectives that must be at the core of any EAA are: ensuring ecological well-being, ensuring human well-being, and ensuring the ability to achieve (governance and external factors). Contained within the EAA is the recognition that trade-offs must be made in order to reconcile different objectives. Stakeholders must identify, prioritize and address issues, considering the impacts of both the inputs and outputs of aquaculture. In order to address climate change issues using EAA, it is necessary to begin by identifying the physical aspects in order to understand the ecological impacts and the resulting social consequences on the sector.

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[1] The Regional Commission for Fisheries (RECOFI) carries out its functions and responsibilities in the region, bounded in the south by the following rhomb lines: from Ras Dhabat Ali at 16°39’N, 53°3’30"E to 16°00’N, 53°25’E, then to 17°00’N, 56°30’E, then to 20°30’N, 60°00’E, then to Ras Al-Fasteh at 25°04’N, 61°25’E. Membership includes: Bahrain, Iran (Islamic Republic of), Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.

Plenary discussion

What is the role in stock enhancement for helping to minimize risk?

It is necessary to first do a risk assessment and be clear about objectives. In many cases, stock enhancement has been successful. There are success stories with tilapia, but there are negative impacts, which must be taken into account and all stock enhancement must be taken on a case-by-case basis.

What lessons learned in agriculture can be applied to aquaculture management?

Several studies have investigated this. We are putting more effort into integrated aquaculture and integrated planning and trying to avoid the mistakes of agriculture, but this is not an easy task. Many of the lessons learned from agriculture are applied in aquaculture. Attempts to lower inputs and decrease intensity are examples of this.

Adapting to climate change: the ecosystem approach to fisheries and aquaculture in the Near East and North Africa Region, by C. De Young (FAO), G. Bianchi (FAO), and Y. Ye (FAO)

The EAF is the realization of sustainable development in fisheries, stressing holistic, integrated and participatory processes. The purpose of an EAF is to plan, develop and manage fisheries in a manner that addresses the dynamic nature of societies' needs in a way that ensures the sustainability of aquatic ecosystems. The EAF is based on principles that pull together existing instruments and agreements in order to realize sustainable development in fisheries, stressing holistic, integrated and participatory processes. The key features of the EAF are maintaining ecosystem integrity while improving human well-being and equity and promoting an enabling governance.

The need for an EAF stems from a number of factors, including: poor performance of current management practices; degradation of fishery resources and the marine environment; and recognition of a wide range of societal interests in aquatic ecosystems and the need to reconcile these.

Key principles that should be considered in practice are: apply the precautionary approach; use best available knowledge; acknowledge multiple objectives and values of ecosystem services; embrace adaptive management; broaden stakeholder participation; understand and use a whole suite of management measures; and promote sectoral integration and interdisciplinarity.

Plenary discussion

Is the application of the EAF feasible only at a regional level, or can it also be applied at a local or small-scale level?

Generally, community-based and comanagement-styled approaches use elements of the EAF already, but it is called something different. Depending on the level, we may not have all the information required, but the EAF is about using what information is available in the best possible way, thus the EAF can be applied at different scales. The EAF is primarily about decision-making for achieving well-defined objectives, based on the best available knowledge. Potential effects and consequences at the systems level of management decisions must be considered. However, even simple models of systems' functions can establish a plausible subset of potential outcomes and improve transparency in decision-making. At higher levels, for example, the large marine ecosystem (LME) level, implementation may be blocked by a perceived need for further information, whereas at a smaller level we can often go ahead.

Climate change and fisheries, by M.C. Badjeck (WorldFish) and E.A. Allison (WorldFish)

The fisheries industry comprises 8 percent of global employment and has a global trade value of almost USD80 billion. In Mauritania, Morocco and Yemen, fisheries exports comprise over 1 percent of exports, as high as 15.8 percent in Mauritania. Climate change will affect fisheries in a variety of ways, including production ecology, fishing operations, communities and livelihoods, as well as wider society and the economy. Different models show that the biomass of certain fish species will shift, and different countries will experience changes with regard to the species in their waters. Countries have different levels of vulnerability to the impacts of climate change on the fisheries sector, and it is necessary to conduct vulnerability assessments to determine the drivers of change in the sector, as well as the adaptive capacity, the coping mechanisms, and resilience to future climate change. Additionally, the opportunities brought by climate change must be capitalized on, combined with adopting a multisectoral approach in order to address the conflicts and synergies between adaptation strategies.

Plenary discussion
What components are used to determine national-level vulnerability to climate change?
To determine vulnerability, exposure, sensitivity, potential impacts and adaptive capacity were all analysed.

Are there positive opportunities? How can we take advantage?
Through migration and changes in movements of various species, some will lose, some will gain. Also, species will migrate within countries. In order to take advantage of these changes, it is necessary to gain an understanding of where these changes will occur and develop a strategy to adapt to them.

Aquaculture and climate change, by M.C.M. Beveridge (WorldFish), M.J. Phillips (WorldFish) and A.R. el-Gamal (WorldFish)
Over the past two decades, aquaculture has consistently been the fastest-growing food production sector in the world, and now accounts for half of all fish consumed (FAO, 2009).
Worldwide, it generates tens of millions of jobs, directly and indirectly. As the evidence that the climate of the earth is changing profoundly grows stronger, it becomes necessary to address how aquaculture will be affected. Climate-change–aquaculture interactions are two-way – aquaculture contributes to climate change, and climate change affects aquaculture. The impact of the interactions on linked social-ecological systems, however, must be considered in the context of other pressures: changes in population size and demographics, environmental degradation, market, globalization, energy prices, health and economic recession. The impacts of climate change on aquaculture include: distribution, productivity, species availability, growing season, feed and seed costs, cash flows and profitability, pond flooding, hazardous working environments, damage to assets, increased insurance costs and planning.

Plenary discussion
One obstacle for aquaculture development is the financial crisis and energy cost. In the RNEA, shouldn't European Union companies invest in offshore cage aquaculture in order to reduce costs and develop technology?
Unless there is a market, investment in these areas will not occur. If you can produce what the market demands, for the right price, then investment will occur. There is a comparative value missing from this analysis. Of course, it is necessary to understand the impacts of fishing/aquaculture, but also to make a comparison with meat and vegetables. People need to know the impacts of their choices not just on the environment but also on livelihoods.

1.2.2 Regional papers

Climate change and the ecosystem-based approach to fisheries and marine aquaculture for Mauritania and Morocco, by A. Orbi (INRH), S. Zizah (INRH), K. Hilmi (INRH) and M.Y. Allaroussi (Ministry of Agriculture and Fisheries, Morocco)
The Mauritanian and Moroccan waters are part of the Canary Current Large Marine Ecosystem (CCLME), which hosts high productivity due to a key eastern boundary upwelling ecosystem. In both countries, there is a wide variety of small pelagic species, with significant variability in their biomass and distribution. The fisheries sector in Morocco contributes between 2 and 3 percent of gross domestic product (GDP), directly creates 170 000 jobs (1.5 percent of the workforce) and 490 000 jobs indirectly. Capture fisheries annual production is 1 million tonnes, and while Morocco is developing its aquaculture sector, it is still very marginal. In September 2009, the Government of Morocco adopted a new fisheries strategy, Halieutis, which includes sustainability and the recognition of aquaculture as a strong driver of growth in its key objectives.

The fisheries sector in Mauritania accounts for 6–10 percent of GDP, and provides approximately 30 000 jobs, or 36 percent of modern sector employment in the country. The overall volume of exports has been declining in recent years, and many high-value species are in a state of overexploitation. The fisheries sector is experiencing increased pressure due to illegal fleet fishing in prohibited areas, intensified competition between artisanal fisheries and industrial fisheries, as well as the use of prohibited fishing gear.

In 2006, Mauritania adopted a new fisheries strategy, which includes the optimization of the contribution of the sector to the economy, sustainable management of resources, and safeguarding of the maritime environment.

In the new fisheries strategies of both countries, vulnerability assessments were not conducted, and so the vulnerability to climate change must be estimated from general climate-change impact studies.

Plenary discussion
What regional cooperation between Mauritania and Morocco currently exists?
There is currently close cooperation between Mauritania and Morocco, in both an administrative sense as well as meetings within the private sector on issues that overlap. With respect to Morocco's new strategy, the objective is to fill knowledge gaps with a sustainable use of resources. The Ministry of Fisheries is trying to convert scientific issues into practicable issues through consultation with stakeholders; it is adaptable to address emerging issues.

The ecosystem-based approach to fisheries and aquaculture for the Southern and Eastern Mediterranean, by M. Belhassen (INSTM, Tunisia)
In general, the subregion is under the influence of a Mediterranean climate, characterized by mild wet winters and by warm to hot, dry summers. Because of its latitude, the Mediterranean Sea is located in a transitional zone where both mid-latitude and tropical variability are important and compete against each other. Freshwater resources are very limited and are under increasing pressure in terms of both quantity and quality, with the exception of Egypt. The seawater is characterized by limited productivity, but it hosts one of the richest biodiversities in the world. An important feature of this subregion is the emergence of highly populated societies, with an estimated 140 million people.

The fishing activity is characterized by the dominance of an artisanal (coastal) sector, the slight growth of an industrial sector, and by a large dispersion of fishing and marketing along the coast. The fisheries of the region are based on relatively poor resources and often exploited by individuals with low-cost vessels and simple gear. In the southern and eastern Mediterranean Sea, fisheries and aquaculture fishing have had significant effects on livelihoods, employment opportunities and foreign exchange earnings to the countries of the region. With regard to aquaculture, there are significant differences in aquaculture quantities produced by countries, Egypt being at the forefront of aquaculture activity in the subregion.

The subregion appears as one of the most threatened regions in the world by climatic change. The countries in the subregion have limited levels of services, technological and economical resources, which are likely to result in very restricted adaptation capabilities to environmental and climate changes.

Plenary discussion
With regard to species distribution, is this being observed or monitored between the Mediterranean and the Red Sea?
The environment is changing, which will impact migration, but this is relatively new and while there have been observations of species having moved, there is not a formal monitoring system in place.

There are a lot of fish imports in this subregion, why can't that gap be filled with aquaculture?
In general, prices for aquaculture in the North Africa region are not competitive, as the aquaculture sector is only developed in certain countries. However, this is an issue that could use further exploration in order to understand further what role the development of aquaculture could play in reducing fish imports.

The ecosystem-based approach to fisheries and aquaculture for the Red Sea and Gulf of Aden, by M.M.A. Zaid (Al-Azhar University, Egypt)
The RESGA subregion includes the coastal areas of seven different countries, of which four are the focus for this workshop; Egypt, Jordan, Saudi Arabia and Yemen, representing approximately 96 percent of regional production. Fishing in the RESGA subregion is dominated by small-scale, artisanal activities. According to the available information about these countries, the artisanal and industrial fisheries produced approximately 30 269 tonnes of invertebrate species and 261 842 tonnes of finfishes in 2007. The subregional artisanal fleet

operating in the area is comprised of approximately 54 500 fishers and about 15 500 vessels of different types, while the industrial fleet is comprised of about 12 057 fishers and 1 600 industrial vessels. The marine aquaculture in the area is mainly limited to Saudi Arabia and Egypt, with aquaculture representing 14 percent of total fish production in Saudi Arabia. In the RESGA subregion, climate change is an additional pressure on top of the many (fishing pressure, loss of habitat, pollution, disturbance, etc.) that the marine environment already experiences. This means that the impact of climate change must be evaluated in the context of other anthropogenic pressures, which often have a much greater and more immediate effect.

Plenary discussion
As far as the introduction of new species is concerned, has there been any link between species composition and water quality levels?
It is difficult to evaluate new species in the RESGA subregion, as there is a lack of proper fisheries data, and a lack of coordination between countries, despite the presence of the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA). This all makes it difficult in the discovery of new species in the area.

Does this impact the reliability of the data on fisheries catches in the RESGA subregion?
Reliability of catch data is an important problem, particularly as it is common with small-scale, artisanal fisheries, and these are the activities that dominate the subregion.

Adapting to climate change in the RECOFI subregion, by H. Negarestan (IFRO, Iran [Islamic Republic of])
The RECOFI is a regional fishery body covering a body of water with the membership of eight countries, including Bahrain, Iran (Islamic Republic of), Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. The climate is of a subtropical nature. Salinity is high compared with neighbouring marine environments. Freshwater input is low and is only from the Arwand River, which collects water from the Karoun, Euphrates and Tigris Rivers.

Artisanal fisheries are of great importance in the RECOFI area, including a large number of fishers with small incomes. Modern fisheries of various types are also present in the subregion, however, not at a high intensity level. Aquaculture is limited to land-based shrimp culture, and an extensive cage culture of marine species. However, it is developing quickly and has increased almost five times during the last decade.

Fisheries management is practised separately in each country. The present approach to solving fish stock problems is based on concentrating on fishes grouped according to fishing gear. Some species have been given special attention. While there is little evidence that climate change has caused any change to the fisheries sector so far, the RECOFI subregion is highly sensitive to possible fluctuations caused by climate change in the future, particularly as there is a predominance of low-income artisanal fishers in the subregion. In recent decades, the subregion has experienced rapid development in the coastal zone and a loss of potential to sustain coastal and marine populations of fish. An integrated EAF in the subregion is necessary.

Plenary discussion
There was a large fish kill in 2005 in Kuwait, and it was suspected this was from humidity and high sea temperatures, the most affected fish was the mullet. While there are no answers as to why, is it not possible this subregion is already feeling the effects of climate change?
Some people say it was from a high amount of sewage in the area. However, this is not a phenomenon that is occurring in isolation, the sewage was there for years. As things change in the subregion, and with the combination of anthropogenic changes with climatic changes, unpredictable impacts will result.

1.3 Working group sessions

The working group sessions were divided into three main topic areas:

- identifying climate change impacts on fisheries and aquaculture;
- identification of adaptation/management strategies for priority impacts/issues;
- understanding regional and subregional capacity for the implementation of adaptation strategies.

The first two working group sessions were divided by expertise with regard to either capture fisheries or aquaculture, while the third working group session was divided by subregion. The working group sessions were designed to incorporate the EAF and EAA into the discussions. This ensured that the biophysical well-being, social and economic well-being, as well as governance and ability to achieve were all considered in the sessions.

1.3.1 Working Group Session 1: Identifying climate change impacts on fisheries and aquaculture

The participants were divided into two working groups, capture fisheries and aquaculture. The working groups used the EA to identify climate change impacts and how they would create issues for ecological well-being, human well-being, and governance and the ability to achieve. Once the impacts and issues were identified and discussed, the working groups prioritized these issues, voting in each category. The outputs of the working groups are detailed in Tables 1.1 and 1.2. These reflect the discussions for identifying the impacts as well as the prioritization through voting. The key for these tables is below.

Capture fisheries

The capture fisheries working group recognized that freshwater systems will be affected by climate change; however, it decided to focus on marine fisheries, as each type warrants its own investigation and the time did not allow for an exploration of both. A variety of issues created by the effects of climate change were raised and discussed for each component of the EAF. However, the voting revealed a clear preference for the prioritization of certain key issues over the others (Table 1.1).

In the category of ecological well-being, the two main priorities selected were recruitment and life cycle, as well as changes in habitat structure. Where recruitment and lifecycle encompass a more macro-level issue, changes in habitat structure will address biotic and abiotic factors on the environment. These two issues were priorities in each of the four subregions represented in the group.

In the category of social and economic well-being (human well-being), employment and factors relating to livelihood (revenue change) were highlighted as the key issues. This is reflected in the issues raised in this category – of the eight raised, seven were focused on livelihoods, and only one on the demand side of this industry.

The governance and ability to achieve voting revealed that socio-economic instability relating to unemployment, as well as access rights, were the priorities when compared with the other issues raised by the working group. This again reflects the emphasis that livelihood development and secure employment plays in the capture fisheries industry.

Table 1.1 Identification of climate change impacts on capture fisheries

Marine capture fisheries					
Identification of climate change impacts					
Ecological well-being	Priority	Human well-being	Priority	Governance and ability to achieve	Priority
Recruitment and life cycle		Production: asset distribution conflicts		Conflict between communities	
Species distribution and composition (biodiversity)		Revenue changes		Change in community level management, access rights	
Nutrients and red tide		Changes in fishing areas (migration)		Government instability (socio-economic)	
Changes in habitat structure		Livelihood changes, no jobs		Conflict between countries	
Increase in sedimentation		Property destruction		Loss of coastal protection	
		Changes in demand (quality issues and health)		Fishing regulation legislation	
		Reduction (GDP)		Fishing licence control	
		Overall employment		Ability to provide jobs and compensation (livelihood options)	

Key:

Highest no. of votes	Middle range of votes	Low no. of votes	No votes

Table 1.2 Identification of climate change impacts on aquaculture

Aquaculture					
Identification of climate change impacts					
Ecological well-being	Priority	Human well-being	Priority	Governance and ability to achieve	Priority
Water quality		Social conflict over resources		Climate-change-proofing policies, planning and implementation for aquaculture	
Climate events		Change in production costs		Lack of intersectoral coordination	
Feeding		Limited availability of sites		Lack of adequate integrated monitoring and warning systems	
Red tide		Job losses		Coastal zone management planning adequate for aquaculture under climate change threats	
Freshwater limitation		Loss of essential infrastructure		Climate change information, dissemination and training	
Sea level rising		Food safety		Long-term investment threatened	
Fish mortality, diseases		Markets and prices		Insurance	
Less wild feed		Food security			

Key:

Highest no. of votes	Middle range of votes	Low no. of votes	No votes

Aquaculture

The working group focusing on aquaculture revealed slightly different results from the capture fisheries working group. The voting was not as clearly in agreement for two priorities in each component of the EAA, and the selected priority issues revealed a different focus. While in the ecosystem/biophysical well-being category, water quality emerged as the priority, climate events, red tide, freshwater limitation and fish mortality diseases are all of concern (Table 1.2).

The issues prioritized with respect to social and economic well-being reflected a more demand-determined approach, with food security and food safety raised as key, with job losses as one of the least important of those raised. Compared with capture fisheries, the issues raised in aquaculture more evenly reflect different components of the production process. In addition, the issues raised in the component on governance and ability to achieve are of a more technical nature for the development of aquaculture.

Discussion
The plenary discussions focused on two main topics: employment, and the degree and type of impacts. Employment was ranked as the top priority in capture fisheries, but did not receive any votes in the aquaculture working group.

Possible reasons identified include:

- Aquaculture is based on technology, so may have a higher adaptive capacity. Capture fishers are generally quite poor and have lower resilience, adaptive capacity.
- All countries in the region have a strong tradition of capture fishing, so a larger number of people rely on capture fishing. Aquaculture is only developed in some of the countries in the region.
- Contrary to this, capture fishers are accustomed to migrating to other locations when weather patterns change, while aquaculture is fixed in one place, raising the point that capture fisheries may be less vulnerable than aquaculture.

The degree and type of impacts were raised mainly in discussion with respect to aquaculture. Aquaculture is extremely dependent on freshwater and the increased salinization of water will create challenges to the operation of aquaculture. In addition, aquaculture planning is not prevalent in government climate change adaptation strategies; it is often not considered as much as capture fisheries, as there is such high employment in capture fisheries.

It was also pointed out that it is important to recognize that climate change impacts will result in changes, but they will not all be negative. The exact impacts with respect to fisheries have not been identified, and there will be winners and losers as a result of the changes. The impacts and issues addressed in the working group discussions reflected this, as it was recognized that an issue identified as a change could be either positive or negative.

1.3.2 Working Group Session 2: Identification of adaptation strategies for priority issues

The working groups remained the same as in the first working group session, divided into aquaculture and capture fisheries. One or two of the priority issues identified in the first working group session for ecological well-being, human well-being and ability to achieve were used for the discussion for possible adaptation strategies. Possible adaptation strategies were discussed, and a number of strategies were highlighted as effective for implementation on different scales. While issues such as expense, ease of government change, and availability of technical expertise were raised in the discussion of these options, the overall capacity for the implementation of these strategies was not a primary factor for choosing them, and the topic was reserved for the following session. In the capture fisheries working group, the most appropriate levels for implementation were identified as local, national and regional, while for aquaculture the levels were identified as farm, watershed and national. It was noted that regional was not an appropriate scale of management for aquaculture. However, the watershed is often transboundary and the relevant international body would participate in the implementation of any watershed management strategy. The results of the working group discussions for capture fisheries and aquaculture are highlighted in Tables 1.3 and 1.4.

Capture fisheries
The capture fisheries working group first dealt with the adaptation strategies which would most effectively address each of the priority issues, and then with the level at which they would most effectively be applied. The levels for the application of adaptation strategies for marine fisheries were defined as local, regional and national. The strategies raised and discussed were of a holistic nature, which not only addressed the issue on its own but involved assessments and strategies that explored the nature of the issue itself. The options explored (see Table 1.3) also addressed the need to gain a comprehensive understanding of the problems; develop a more robust knowledge of the issues; as well as to adopt a precautionary approach with respect to any management strategies.

Aquaculture

The working group initially defined that the most appropriate levels for adaptation strategies would be at the farm level, watershed level, and country level. The adaptation strategies discussed are detailed in Table 1.4. The discussion focused on how adaptation strategies could be applied at one level while being enhanced at further levels, e.g. better management practices (BMPs) applied at the farm level, enhanced at the watershed level and again at the national level.

Also, the importance of setting standards in one country while recognizing the impacts of standard setting by another country necessitated the application of actions/strategies at the regional level. A difficulty is that standards are often set by other countries, and so standard setting is seen as an action/strategy at the regional level.

Discussion

While the working group discussions were mainly focused on what can be seen in Tables 1.3 and 1.4, in each group the notion was raised that the ways in which these two sectors interact with other sectors must be considered. The working group focusing on aquaculture found that, with increasing competition for resources, in some countries poultry and fish often substitute for one another, so that when changes occur in one, this often has significant impacts on demand for the other.

The interaction and integration of aquaculture and capture fisheries was also addressed. In the Islamic Republic of Iran, tuna capture fisheries are often complemented by tuna aquaculture, so that aquaculture often enhances the incomes of tuna fisheries, instead of creating competition for jobs. In other countries, however, those most adept at aquaculture were farmers, not fishers, and so aquaculture cannot be viewed in all cases as a replacement for unemployment in the capture fisheries industry. In some cases, it is found that there is a greater role for women in aquaculture than fishermen, creating an interesting gender dynamic when analysing the two industries. While the role of women in the fisheries sector varies from country to country, and between the fisheries and aquaculture sector, they are generally a vulnerable group in the industry, and training to increase the adaptive capacity of all vulnerable groups must be considered.

The role of the government in most of the strategies adopted above appears to be quite strong, in both aquaculture and capture fisheries, and throughout the region. While it was discussed and is recognized that many of these strategies will be best implemented at the community level, there is a tendency within the region to involve the government in all levels of management implementation. Implementation solely at the community level will take time for both the communities and the governments to become comfortable. As long as governments play a role in the implementation of these strategies, the effectiveness will be limited by government strategies overall, as well as by competition between sectors for government resources. Moving towards comanagement and the private sector could also relieve some of the financial pressures on government, particularly in the technology-intensive aquaculture industry, where the private sector has a greater role. The capture fishery business is more traditional and less competitive, so it makes more sense that the government plays a larger role.

Table 1.3 Adaptation strategies for capture fisheries

Marine capture fisheries								
Identification of adaptation and management strategies for priority impacts								
Ecological well-being			Human well-being			Governance and ability to achieve		
Priority impact	Adaptation strategy	Scale for implementation	Priority impact	Adaptation strategy	Scale for implementation	Priority impact	Adaptation strategy	Scale for implementation
Recruitment and life cycle	Life cycle assessment	Regional	Livelihood changes AND revenue changes	Develop and enhance aquaculture practices	National	Government Instability	Capacity building inside the sector to increase the ability to cope with change	Local and national
Changes in habitat structure	Responsible stock enhancement	Local		Explore and implement livelihoods diversification	Local and national		Explore and implement incentive mechanisms for increasing efficiency and increasing livelihood diversification	Local and national
	Coastal habitat restoration	Local		Optimizing the harvest sector	National	Changes in community-level management (access rights)	Establish comanagement systems within legal and policy framework	Local and national
				Adaptive post-harvest and marketing strategies	National and regional			

Table 1.4 Adaptation strategies for aquaculture

Aquaculture								
Identification of adaptation and management strategies for priority impacts								
Ecological well-being			Human well-being			Governance and ability to achieve		
Priority impact	Adaptation strategy	Scale for implementation	Priority impact	Adaptation strategy	Scale for implementation	Priority impact	Adaptation strategy	Scale for implementation
Water quality change	Monitoring system and early warning system	Farm, watershed and national level	Food security	Integrated agriculture aquaculture and development of integrated multitrophic aquaculture (IMTA)	Farm	Climate-change-proofing policies, planning and implementation for aquaculture	Government investment in research to improve aquaculture adaptation and/or facilitate research and information to climate-change-proof aquaculture	National
	Set up a biosecurity framework	Watershed		Raise awareness about integrated aquaculture to improve food security including IMTA	Watershed			
Extreme climate events	Preparedness of the farmers to improve farming systems, face extreme events.	Watershed		Research and experimentation with new species	National		Farmers organized are better prepared. Enhance farmers associations	Watershed
				Incentives for diversification, new markets and new species promotion	National			
	Set up a biosecurity framework	Watershed		Better management practices, including training and incentives for training	Farm, watershed, country		Governments should facilitate the production of local vulnerability maps and risk maps	National
	Use local knowledge and local logistics to disseminate information	Watershed	Food Safety	Standards setting	National			
				Food safety controls created by public-private cooperation, governments facilitate transparency	Watershed and national		Government institutions could be improved to enhance cross-sectoral cooperation and coordination	National
	Ensure the provision and access of early warnings by farmers.	National		Toxics monitoring, classifying areas for different kinds of farming, i.e. red tides and other pollutants	Watershed (but facilitated by national governments)		Make efforts to develop a country aquaculture strategy and plan considering climate change	National
	Facilitate education and readiness	National		Sharing information in the region	Watershed (but facilitated by national governments)			

1.3.3 Working Group Session 3: Understanding regional and subregional capacity for adaptation strategies

The final working group session addressed the capacity of the subregions to implement effectively the adaptation strategies from the previous working group session. The working groups were divided into subregions, the Mediterranean and Atlantic forming one working group, the RESGA and RECOFI forming the second working group. The working groups voted on adaptation strategies and then assessed the subregional capacity for implementation of these strategies using the following indicators:

- institutional capacity
- financial capacity
- human capacity
- willingness

The adaptation strategy was assessed based on each of the above criteria, and then an analysis was undertaken in the plenary discussion to determine where capacity strengths and weaknesses exist in the subregions.

Mediterranean and Atlantic subregions
The assessments in this working group were based on a percentage system. Each participant voted on one option strategy for each component of the EA. Then, the capacity for each option was ranked using: 1 = non-existent, 2 = moderate 3 = good. Following this, the overall capacity for each indicator was assessed using a grading system:

80–100 percent = very good
60–79 percent = good
40–59 percent = average
0–39 percent = poor

The results of this working group session for the Mediterranean and Atlantic subregions are detailed in Tables 1.5 and 1.6, respectively.

Table 1.5 The capacity for implementation of adaptation strategies in the Mediterranean

Mediterranean						
Indicators	Capacity for strategy implementation					
	Ecological well-being		Human well-being		Governance & ability to achieve	
	Life-cycle assessment	Monitoring and early warning	Optimizing the harvest sector	Integrating aquaculture and agriculture	Capacity building inside the sector	Planning aquaculture
Institutional	Good	Good	Good	Good	Very good	Good
Financial	Good	Average	Good	Average	Good	Good
Human	Average	Average	Average	Average	Good	Good
Willingness	Good	Good	Good	Good	Very good	Very good

Table 1.6 The capacity for implementation of adaptation strategies in the Atlantic

Atlantic						
Indicators	Capacity for strategy implementation					
	Ecological well-being		Human well-being		Governance & ability to achieve	
	Life-cycle assessment	Monitoring and early warning	Optimizing the harvest sector	Integrating aquaculture and agriculture	Capacity building inside the sector	Planning aquaculture
Institutional	Very good	Average	Good	Good	Good	Good
Financial	Average	Poor	Average	Poor	Good	Poor
Human	Good	Average	Average	Poor	Average	Average
Willingness	Very good	Average	Good	Good	Good	Good

The RECOFI and RESGA

The working group for the RECOFI and RESGA subregions chose adaptation strategies that could be applied to both aquaculture and fisheries throughout the two subregions. The three strategies selected, as well as the capacity for the implementation of these strategies, is detailed in Table 1.7. The capacity assessment criteria chosen were: not present, being established and established. Where there was variance between countries, a range was stated.

Table 1.7 The capacity for implementation of adaptation strategies in the RECOFI and RESGA

RESGA and RECOFI			
Indicators	Capacity for strategy implementation		
	Ecological well-being	Human well-being	Governance and ability to achieve
	Ecosystem monitoring system with early warning system	Creating and enhancing adaptive fisheries and aquaculture practices	Country fisheries and aquaculture strategies and supporting plans of action to consider climate change
Institutional	Established	Being established	Being Established
Financial	Varies between not present and established	Not present	Being Established
Human	Varies between being established and established	Varies among countries from not present to being established	Being Established
Willingness	Being established	Being established	Varies between being established and established

Discussion

Aquaculture varies among countries in the same region, making it difficult to cast an overall vote on issues, and initiatives and planning for the integration of aquaculture and other sectors were limited to specific countries and non-existent in others.

At the regional level, there seems to be a willingness to implement capacity building in the fisheries sector, while there is a lack of assessment of the effectiveness of the capacity building actions already implemented in the area.

Institutional capacity in all subregions is quite good, encompassing research, administration, policy and legal frameworks. However, operational capacity (finance and human) is moderate to low in all subregions, and this is something that will pose an important challenge that must be considered when designing adaptation strategies.

1.3.4 Conclusions and recommendations

Climate change impacts bring increasing pressure on the fisheries and aquaculture sectors in much of the Region and are understood to be an additional pressure on fisheries that are not adequately managed. While reducing the vulnerability of capture fisheries and aquaculture is an objective of some strategies in the region, it has yet to be effectively implemented. Regarding capture fisheries, the Region as a whole, as well as the subregions specifically, is not prepared to cope adequately with the additional pressures that climate change will create. It is clear that the fisheries and aquaculture industries must adopt adaptation strategies on a variety of levels in order to prepare adequately for the impacts of climate change. While it is generally acknowledged throughout the Region that preparation for climate change is necessary, the required capacity to implement the appropriate strategies effectively still needs to be developed. Information and experience sharing between countries and subregions could reduce the negative impacts of this gap in capacity in certain countries.

A common understanding of the EAF and EAA concepts is developing, and an effort is now being made to incorporate the principles of EAF and EAA in policies at the national level in certain countries. However, there is still much to do to make these principles operational in the practical management of fisheries. Lack of institutional, financial, human and willingness capacity for implementation at the local, national and regional (including watershed) levels must be recognized and addressed in order for the successful implementation of the EAF and EAA in the subregions.

There is a general lack of reliable data in the capture fisheries industry. This issue needs to be addressed in order for the implementation of effective management strategies in general, as well as climate-change adaptation strategies. Developing strategies to adapt to climate change will not only minimize the effects experienced from climate change impacts, but can also reduce vulnerability to other changes and increase the resilience of the industry.

2. TECHNICAL PAPERS

Background technical papers were presented and submitted in order to provide workshop participants with a basic knowledge of some of the specific topics that would need to be addressed, including the impacts of climate change on the Region, and on fisheries and aquaculture, as well as the components of the ecosystem approach which are relevant to both fisheries and aquaculture. The technical papers were submitted on the following topics:

- Climate change in the Near East and North Africa Region, by H. Kanamaru (FAO);
- Adapting to climate change: the ecosystem approach to fisheries and aquaculture in the Near East and North Africa Region. The ecosystem approach to fisheries and its links to climate change, by C. De Young (FAO), G. Bianchi (FAO), and Y. Ye (FAO);
- An ecosystem approach to aquaculture: a way to facilitate adaptation to climate change, by D. Soto (FAO) and P. White (NIVA);
- Climate change and fisheries, by M.C. Badjeck (WorldFish) and E.A. Allison (WorldFish);
- Aquaculture and climate change, by M.C.M. Beveridge (WorldFish), M.J. Phillips (WorldFish) and A.R. el-Gamal (WorldFish).

2.1 Climate change in the Near East and North Africa Region

Introduction

As the Summary for Policymakers of the Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) concluded: “warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level”. The AR4 found that the understanding of anthropogenic warming and cooling influences on climate had improved since the AR3, “leading to very high confidence that the globally averaged net effect of human activities since 1750 has been one of warming”. In addition, it found that “observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases”.

Although the global signal of climate change is clear, regional and subregional climate change and its effects on natural and human environments are difficult to discern and have been recognized only recently owing to greater natural climate variability at regional scales, local non-climate factors and the limited spatial coverage and short time scales of many studies. The paper summarizes the state-of-the-art understanding of climate change in the RNEA from the IPCC AR4 supplemented by recent literature. The current paper also updates a paper for the FAO Conference for the Near East Region in 2008, which the author co-wrote (FAO, 2008).

Observed and projected changes in climate

Temperature

Global temperature has increased over the last 150 years at the rate of 0.74 °C/100 years. Over the last 50 years, the linear warming trend has been nearly twice the rate for the last 100 years (Figure 2.1). Continental temperature changes for Africa and Asia show a similar trend to the global trend since 1900 (black solid line in Figure 2.2). There is less confidence in temperature time series in Africa earlier in the twentieth century as observed records for that period are scarce. The blue shaded bands show the range of temperature simulated by multiple climate models using only the natural forcings due to solar activity and volcanoes without anthropogenic forcings, namely greenhouse gas (GHG) emissions due to human activities. Only when anthropogenic emissions are taken into account are climate models able to reproduce historical changes in temperature (red shaded bands).

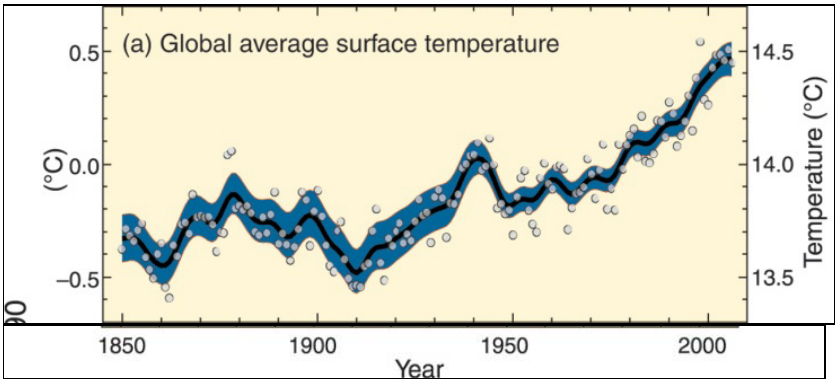

Figure 2.1 Observed changes in global average surface temperature
Source: Figure 1.1 in IPCC, 2007a.

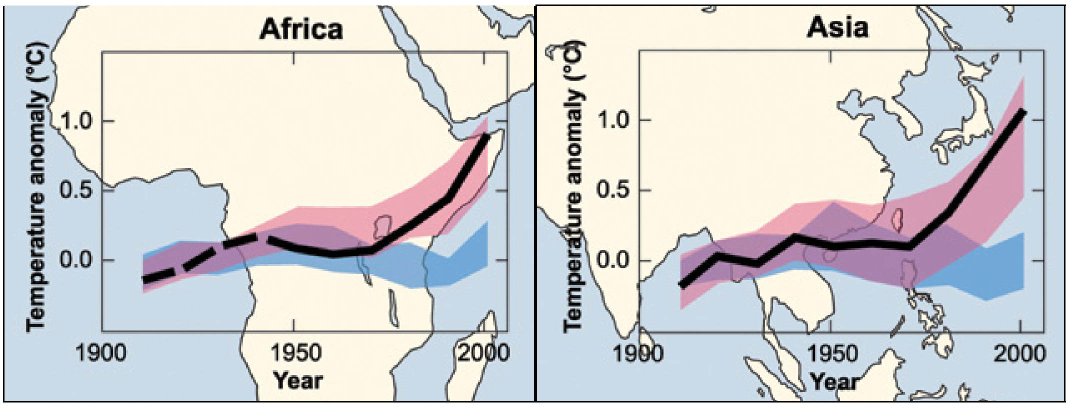

Figure 2.2 Observed continental changes in surface temperature with results simulated by climate models using either natural or both natural and anthropogenic forcings
Source: Figure 2.5 in IPCC, 2007a.

The AR4 concluded that most of the observed increase in global temperature since the mid-twentieth century was very likely due to the observed increase in anthropogenic GHG concentration in the atmosphere. Global GHG will continue to grow over the next few decades, although they will depend considerably on future climate-change mitigation policies and sustainable development practices. The likely range of globally averaged temperature increase by the end of the twenty-first century is 1.1–6.4 °C from a variety of emissions scenarios and climate models (Figure 2.3). The "best estimate" ranges from 1.8 to 4.0 °C for the same set of scenarios and models. For the next two decades, a warming of about 0.4 °C is inevitable regardless of emissions scenarios.

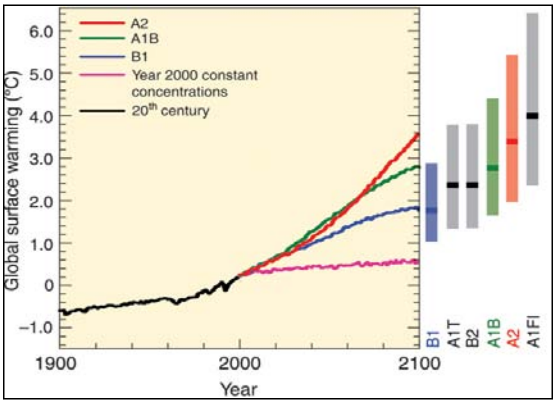

Figure 2.3 Atmosphere–Ocean General Circulation Model projections of surface warming
Note: Solid lines are multimodel global averages of surface warming (relative to 1980–1999) for the Special Report on Emissions Scenarios (SRES) A2, A1B and B1, shown as continuations of the twentieth-century simulations, and for the experiment where concentrations were held constant at year 2000 values.
Source: Figure 3.2 in IPCC, 2007a.

The RNEA encompasses three continental regions (Europe, Africa, and Asia) as defined in the IPCC reports. For the projections of temperature at subregional levels, the closest ones are Southern Europe and Mediterranean (SEM) (the southern part of which covers the coastal area of North Africa) and Sahara (SAH) (which covers the area immediately south of SEM). Annual mean temperatures in these subregions are likely to increase by more than the global mean (Figure 2.4).

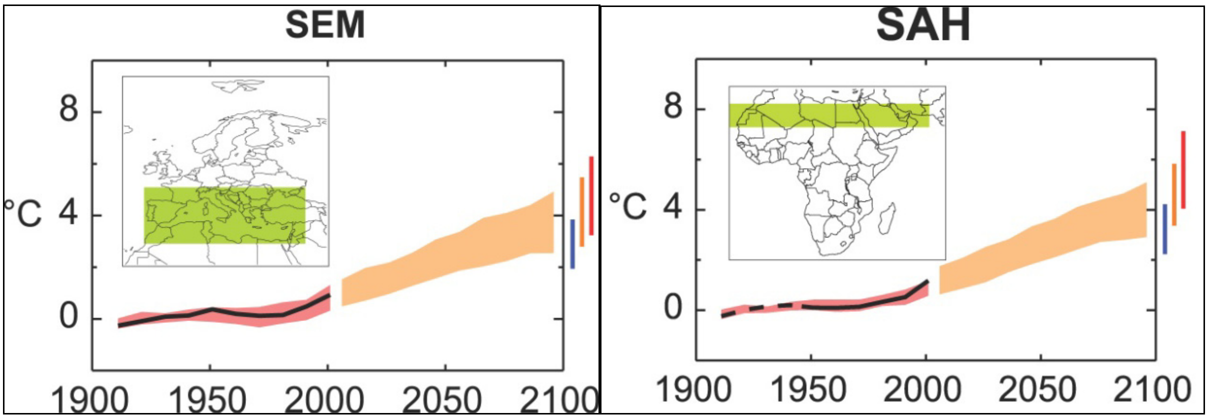

Figure 2.4 Temperature anomalies for the SEM and SAH regions for 1906–2005 (black line) and as simulated (red envelope) by multimodels incorporating known forcings; and as projected for 2001–2100 by multimodels for the A1B scenario (orange envelope)
Source: Figures 11.1 and 11.4 in IPCC, 2007b.

Figure 2.5 shows the geographical pattern of the projected warming for the A1B scenario from multiple model runs. The largest area of projected warming, above 4 °C, is found in the western Sahara while smaller values are found in coastal areas. In the RNEA, the warming is likely to be largest in summer.

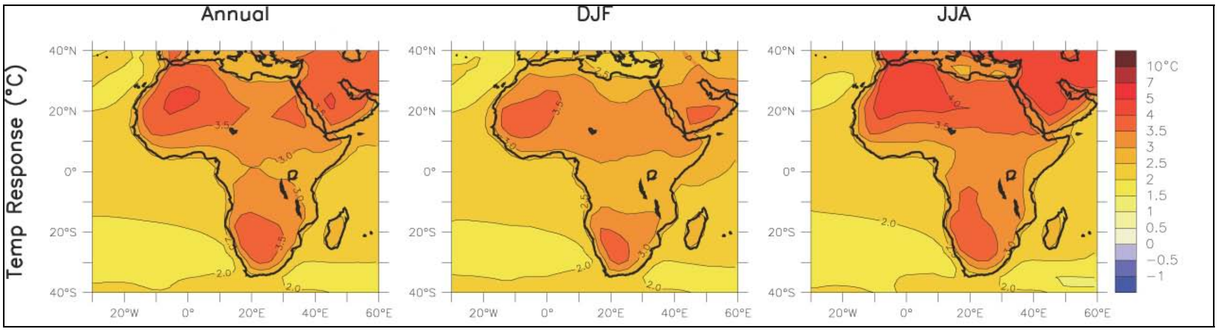

Figure 2.5 Temperature changes over Africa from the multimodel datasets, A1B simulations
Note: Annual mean, DJF and JJA temperature change 1980–1999 and 2080–2099 averaged over 21 models.
Source: Figure 11.2 in IPCC, 2007b.

Precipitation
There is an observed long-term (since 1900) decreasing trend in precipitation in the Mediterranean Basin (Figure 2.6). This general trend is supported by a number of individual studies in the region (e.g. Lebanon [Shaban, 2009]). It should be noted that interannual variability of the Mediterranean rainfall is associated with changes in atmospheric circulation patterns such as the North Atlantic Oscillation (NAO; variability of westerly wind in winter over the North Atlantic). The region experiences a drier winter during the positive phases of the NAO. For example, a more positive phase of the NAO in the 1990s brought drier conditions over the region (Knippertz, Christoph and Speth, 2003; Xoplaki *et al.*, 2004). The rest of the RNEA beyond the Mediterranean Basin is very dry and has insufficient data to establish past trends.

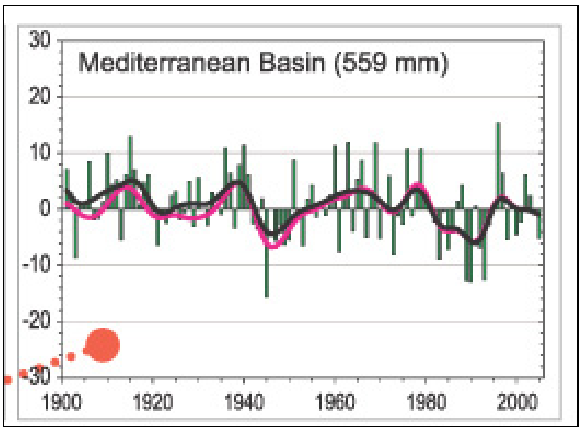

Figure 2.6 Annual precipitation for 1900–2005 (percent of mean, with the mean given at top for 1961–1990) for the Mediterranean region

Note: The Global Historical Climatology Network (GHCN) precipitation from the United States National Climatic Data Center (NCDC) was used for the annual green bars and black for decadal variations, and for comparison the Climatic Research Unit (CRU) decadal variations are in magenta.

Source: Figure 3.14 in IPCC, 2007b.

Generally speaking, increased precipitation is very likely in high latitudes, while decreases are likely in most subtropical land regions (Figure 2.7). This is in line with observed patterns in recent trends.

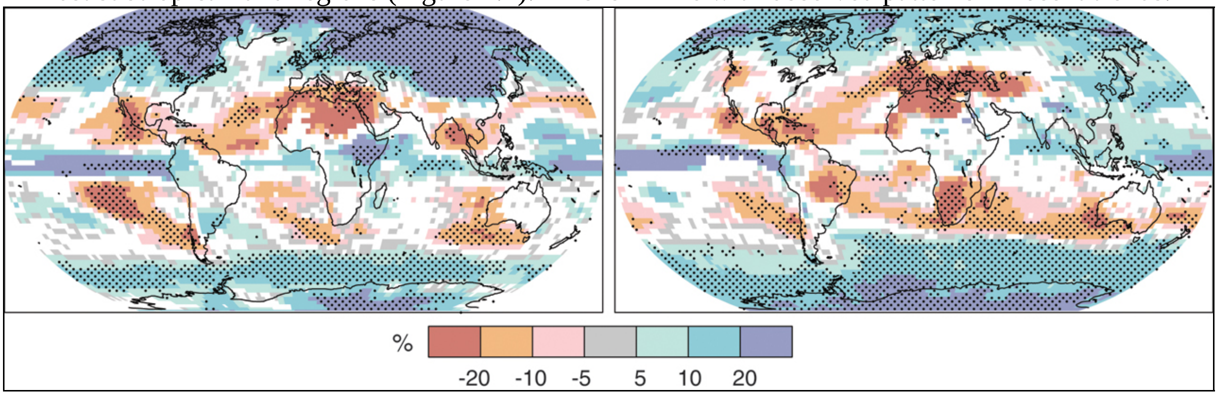

Figure 2.7 Relative changes in precipitation for the period 2090–2099, relative to 1980–1999

Note: Values are multimodel averages based on the SRES A1B scenario for December–February (left) and June–August (right). White areas are where less than 66 percent of the models agree on the sign of the change, and stippled areas are where more than 90 percent of the models agree on the sign of the change.

Source: Figure 3.3 in IPCC, 2007a.

Under future climate-change scenarios, annual precipitation is very likely to decrease in much of the RNEA. In Figure 2.8, the top panels show fractional change in precipitation between 1980–1999 and 2080–2099, averaged over 21 models. Unlike temperature projection, models often do not agree on the direction of change in precipitation. The bottom panels show the number of models out of 21 that project increases in precipitation. Models agree on projected decrease in precipitation over much of North Africa and the northern Arabian Peninsula. Projection of precipitation over the area immediately south of those areas carries large uncertainties, as the area appears as white in the bottom panels.

The likelihood of a decreased rainfall is greater as the Mediterranean coast is approached. The number of precipitation days in a year is very likely to decrease in the Mediterranean area.

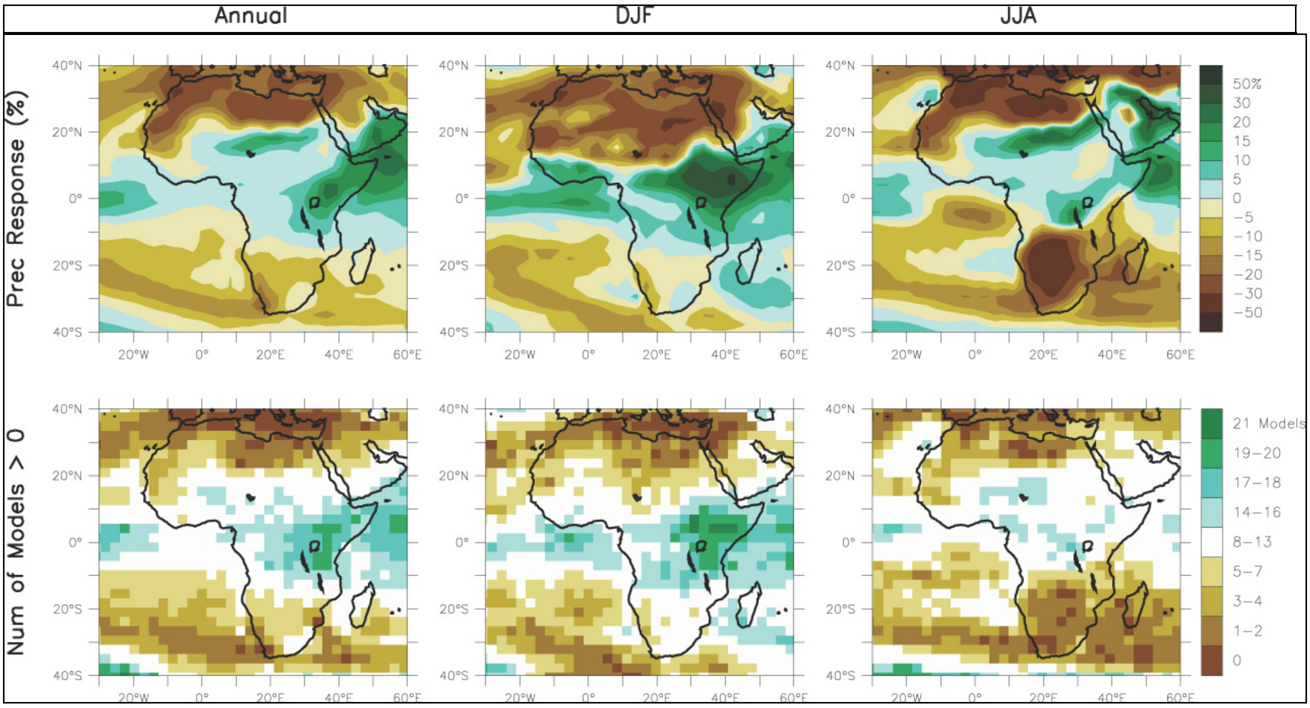

Figure 2.8 Precipitation changes over Africa from the multimodel datasets, A1B simulations
Note: Same as Figure 2.5 but for fractional change in precipitation (top row). Bottom row: number of models out of 21 that project increases in precipitation.
Source: Figure 11.2 in IPCC, 2007b.

Extreme events
Globally, at regional scale, an increase in frequency of hot extremes, heat waves, and heavy precipitation is very likely. On the other hand, there will be fewer cold days and nights. Tropical cyclone intensity is likely to increase. Figure 2.9 shows a schematic diagram of probability distribution of temperature where both mean temperature and variability increase.

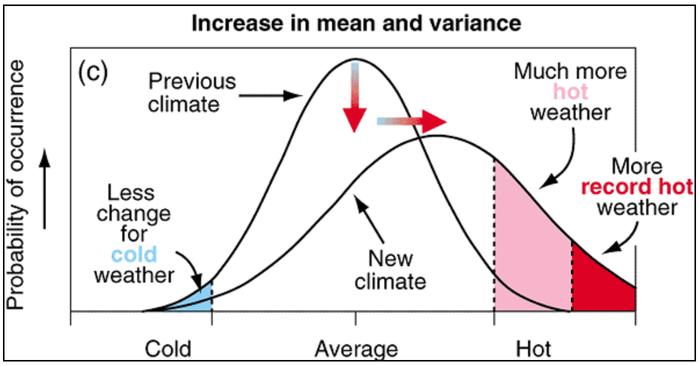

Figure 2.9 Schematic showing the effect on extreme temperatures when the mean temperature increases, for a normal temperature distribution
Source: Box TS.5, Figure 1 in IPCC, 2007b.

For the RNEA, the AR4 was not yet able to provide clear ideas on future changes in extreme rainfall events. It was found, however, that there is generally a decrease in the number of rain days. Consequently, the risk of drought in summer is likely to increase.

Table 2.1 Regional averages of temperature and precipitation projections from a set of 21 global models in the multimodel datasets for the A1B scenario

		Temperature Response (°C)						Precipitation Response (%)						Extreme Seasons (%)		
Region[a]	Season	Min	25	50	75	Max	T yrs	Min	25	50	75	Max	T yrs	Warm	Wet	Dry
SAH	DJF	2.4	2.9	3.2	3.5	5.0	15	-47	-31	-18	-12	31	>100	97		12
	MAM	2.3	3.3	3.6	3.8	5.2	10	-42	-37	-18	-10	13	>100	100	2	21
18N,20E	JJA	2.6	3.6	4.1	4.4	5.8	10	-53	-28	-4	16	74		100		
to	SON	2.8	3.4	3.7	4.3	5.4	10	-52	-15	6	23	64		100		
30N,65E	Annual	2.6	3.2	3.6	4.0	5.4	10	-44	-24	-6	3	57		100		
SEM	DJF	1.7	2.5	2.6	3.3	4.6	25	-16	-10	-6	-1	6	>100	93	3	12
	MAM	2.0	3.0	3.2	3.5	4.5	20	-24	-17	-16	-8	-2	60	98	1	31
30N,10W	JJA	2.7	3.7	4.1	5.0	6.5	15	-53	-35	-24	-14	-3	55	100	1	42
to	SON	2.3	2.8	3.3	4.0	5.2	15	-29	-15	-12	-9	-2	90	100	1	21
48N,40E	Annual	2.2	3.0	3.5	4.0	5.1	15	-27	-16	-12	-9	-4	45	100	0	46

Note: The mean temperature and precipitation responses are first averaged for each model over all available realizations of the 1980–1999 period from the Twentieth Century Climate in Coupled Models (20C3M) simulations and the 2080–2099 period of A1B.
Source: Table 11.1 in IPCC, 2007b.

Temperature and precipitation responses are summarized in Table 2.1. Shaded seasons indicate that most models agree on the projection of precipitation decrease. A decreasing trend of precipitation is clear in the Mediterranean and throughout the year and in the Sahara in winter and spring. The columns on the right indicate the fraction of years that are considered to be extremes under today's climate. By the end of the century, almost all years will be "extremely warm" in both the SEM and SAH and almost half of the years will be "extremely dry" in the SEM.

Sea-level rise

Global average sea level has risen (Figure 2.10) at a rate of 1.8 mm/year (since 1961). The rate of sea-level rise appears to have accelerated recently to 3.1 mm/year (since 1991). Increased temperature has led to thermal expansion and the melting of glaciers, ice caps and the polar ice sheets, which has resulted in sea-level rise.

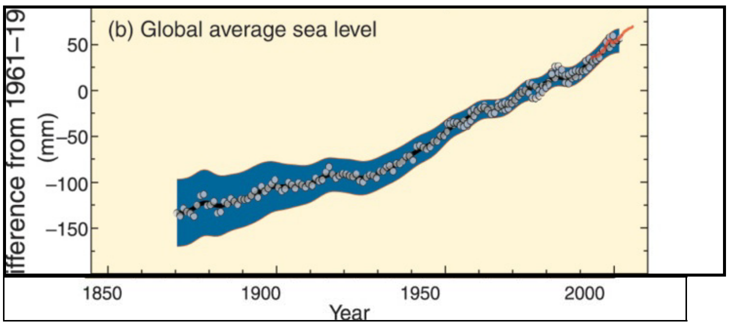

Figure 2.10 Observed changes in global average sea level from tide gauge (blue) and satellite (red) data
Source: Figure 1.1 in IPCC, 2007a.

Projected global average sea level rise by the end of this century is 20 cm or higher, but the AR4 admits that understanding of the sea-level rise mechanism is still insufficient and warns that future sea-level rise may be much higher than is estimated in Figure 2.11 (global average sea level rise for 2090–2099). The projections include a contribution from increased Greenland and Antarctic ice flow (as observed in the past ten years) but do not include uncertainties in climate–carbon cycle feedbacks nor the full effects of ice-sheet flow changes.

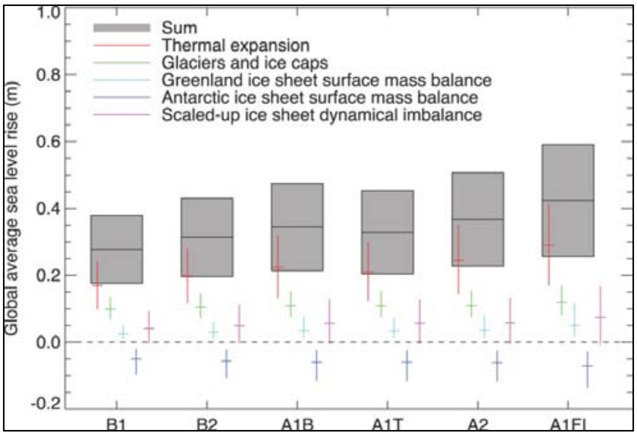

Figure 2.11 Projections and uncertainties (5–95 percent ranges) of global average sea-level rise and its components in 2090–2099 (relative to 1980–1999) for the six SRES marker scenarios
Source: Figure 10.33 in IPCC, 2007b.

The distribution of sea-level rise varies from region to region owing to ocean density and circulation changes. Figure 2.12 shows a distribution of sea-level change from 14 atmosphere–ocean coupled climate models. However, the resolution of global models is not fine enough, and local sea-level rise in the Mediterranean, Red Sea and Persian Gulf is not presented in the AR4. Although good projection of sea-level rise is not available, some parts of the region, notably the Nile Delta and the Persian Gulf coast of the Arabian Peninsula, are expected to be particularly vulnerable to flooding from rising sea levels.

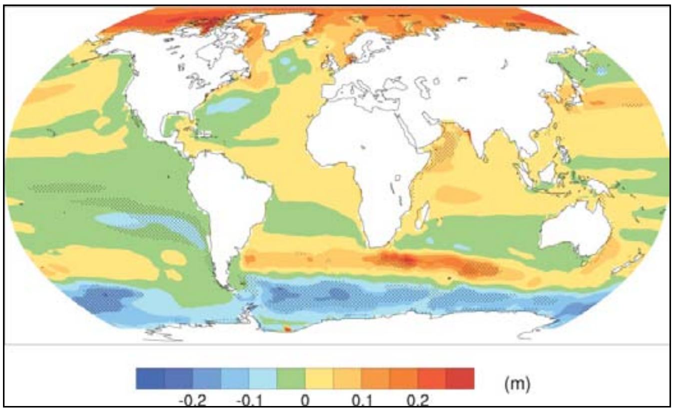

Figure 2.12 Local sea-level change due to ocean density and circulation change relative to the global average during the twenty-first century
Notes: Positive values indicate greater local sea level change than global. Change calculated as the difference between averages for 2080–2099 and 1980–1999, as an ensemble mean over 16 AOGCMs forced with the SRES A1B scenario.
Source: Figure 10.32 in IPCC, 2007b.

Not knowing exactly the extent of sea-level rise in the future, a number of individual studies looked at sensitivities of the region to varying degrees of possible sea-level rise in the region. For example, Al-Jeneid *et al.* (2008) examined a case for Bahrain and found more than 77 km^2 of land area may be inundated under a 0.5 m sea-level rise. El-Raey *et al.* (1999) assessed losses and socio-economic impacts over the Port Said Governorate in Egypt and found some industries may be seriously affected. El-Raey, Dewidar and El-Hattab (1999) and El-Raey *et al.* (1999) discuss adaptation options for Egypt.

Impacts on natural resources and food security

The annex to this paper provides a table of country-by-country overviews on impacts, vulnerability and climate-related risks compiled from national reports to the United Nations Framework Convention on Climate Change (UNFCCC) and disaster database. As is clear from the annex table, freshwater is perhaps the single most important resource for the well-being of people in the RNEA.

Freshwater

Water resources in the RNEA are already under stress from growing population, particularly rapid growth in urban areas, and economic development. Figure 2.13 shows total renewable water resources per capita in 2005. Agriculture accounts for 90 percent of the mobilized water resources, which is around 60 percent of the total renewable water resources in the region.

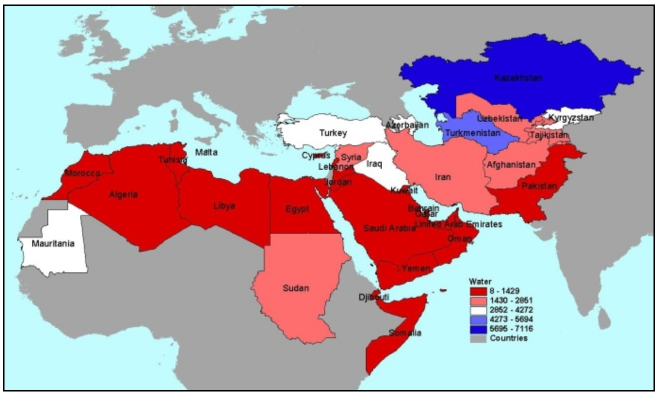

Figure 2.13 Total renewable water resources per capita in 2005, cubic metres per inhabitant per year
Source: FAO AQUASTAT (available at www.fao.org/nr/water/aquastat/main/index.stm).

Climate change is expected to exacerbate the unfavourable situation, with increased temperature and evapotranspiration, and projected decrease in precipitation over much of the Region. Projections of runoff due to changing precipitation and temperature are shown in Figure 2.14. Globally, runoff will increase by 10–40 percent by mid-century at high latitudes and in some parts of wet tropics, and decrease by 10–30 percent over some dry regions at mid-latitudes and in the dry tropics.

For the Mediterranean, more than 40 percent reduction in freshwater availability is suggested by the end of this century along the coastal areas (see also studies such as Abdulla, Eshtawi and Assaf, 2009). It is not known how freshwater availability will evolve in the rest of the RNEA, predominantly desert areas. The Nile River originates in East Africa, where increased precipitation is projected (Figure 2.14). This may have significant implications for future availability of freshwater resources for Egypt (e.g. Sene, Tate and Farquharson, 2001; Strzepek and Yates, 2000; Conway, 2005).

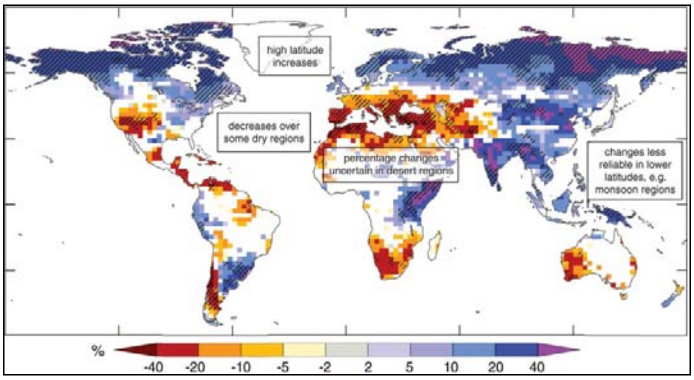

Figure 2.14 Large-scale relative changes in annual runoff (water availability, in percent) for the period 2090–2099 as compared to 1980–1999
Source: Figure 3.5 in IPCC, 2007a.

Areas affected by drought are likely to increase and a number of sectors may suffer, ranging from agriculture and water quality to human health. Many of the irrigation systems in the RNEA are under considerable environmental strain because of salinity, waterlogging or overexploitation of groundwater. Groundwater, including non-renewable fossil water, is of primary importance in most countries. A region-wide increase in irrigation demand is projected in order to maintain food production and sustain growing populations. According to four models, as presented in the AR4, groundwater recharge will decrease dramatically – by more than 70 percent – between now and 2050 along the southern rim of the Mediterranean. Additional concern for the coast areas is sea-level rise, which can compromise freshwater resources by increased risk of salinization of groundwater (e.g. Frihy, 2003).

The Near East and North Africa are particularly exposed to water shortages. An additional 155–600 million people may suffer an increase in water stress in North Africa with a 3 °C rise in temperature. Competition for water within the Region and across its borders may grow, carrying the risk of conflict.

Crop agriculture
All dimensions of food security (availability, stability, utilization and access) will be affected by climate change. Average agricultural yield will increase at high latitudes in cold areas where low temperature is a limiting factor for production. However, even the slightest increase in mean temperature will affect agriculture negatively in warm environments, decreasing average yield (e.g. Koocheki *et al*., 2006a, 2006b; Lhomme, Mougou and Mansour, 2009). Figure 2.15 demonstrates the difference in sensitivity of maize yield at low latitudes and at mid to high latitudes. Global food production may increase with an increase of up to 3 °C average temperature, but beyond this threshold, production will decrease, cereal prices will be higher and developing countries which are already dependent on imports may suffer. Smallholders in Africa and parts of Asia are particularly threatened by climate change. One study estimates up to 75 percent of people from sub-Saharan Africa will be at risk of hunger by 2080.

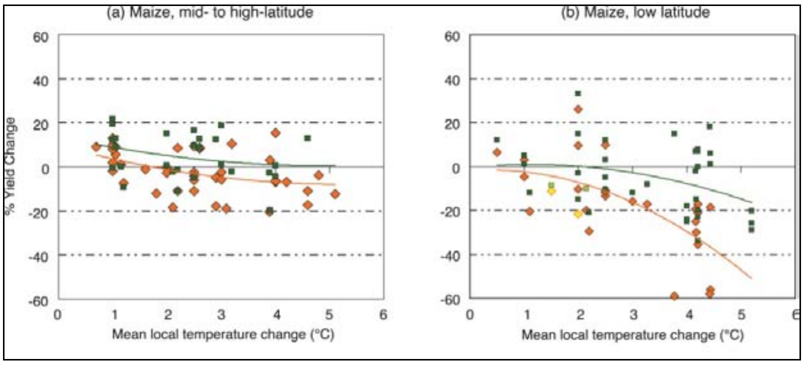

Figure 2.15 Sensitivity of maize yield to climate change
Notes: Derived from the results of 69 published studies at multiple simulation sites, against mean local temperature change used as a proxy to indicate magnitude of climate change in each study. Responses include cases without adaptation (red dots) and with adaptation (dark green dots).
Source: Figure 5.2 in IPCC, 2007c.

A recent FAO study (with the Government of Morocco and the World Bank) provides a good example of possible impact on agriculture production in the semi-arid environment. Rainfed soft wheat yield will keep decreasing towards the end of century (Figure 2.16). Yield decrease beyond 2030 is particularly pronounced. Increased concentration of carbon dioxide in the atmosphere enhances plant growth (carbon dioxide [CO_2] fertilization effect), partly compensating for the negatively affected yield due to temperature increase. However, significant yield decrease by higher temperature and less precipitation tends to outweigh positive CO_2 fertilization. There is still room for agricultural technology development in Moroccan agriculture, such as improved use of fertilizers, introduction of crop varieties better suited to new climate, and mechanization. Continued investment in agriculture research and development is key to sustainable food production as technology may well offset negative impacts of climate change on agricultural production.

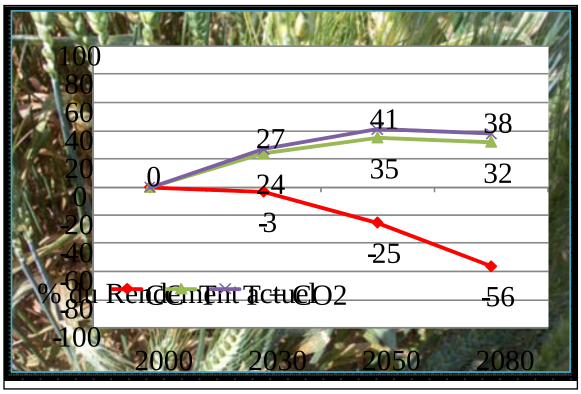

Figure 2.16 Rainfed soft wheat yield projection for the twenty-first century in the “intermediate” agro-ecological zone in Morocco
Source: Gommes *et al*., 2009.

Changes in the frequency of years with poor yields have potentially greater significance for food security than the projection of mean agricultural yields. In the Morocco study, higher interannual variability in temperature and precipitation under climate change scenarios led to a higher incidence of poor yield years (Figure 2.17).

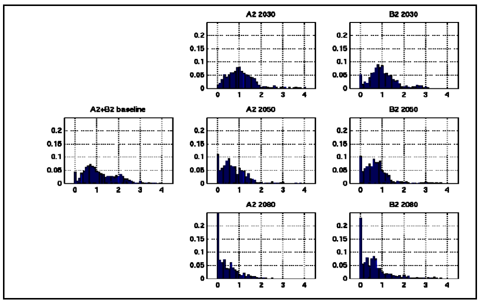

Figure 2.17 Barley projection (probability distribution) for the “intermediate” agro-ecological zone in Morocco
Source: Gommes *et al*., 2009.

In a context where land availability and land degradation are already a major concern for sustained agricultural productivity, changes in temperature, precipitation and weather events will only add to the stress on agricultural resources. Arable land is already limited in the arid and semi-arid areas that cover most of the RNEA, making agriculture potentially highly vulnerable to climate change.
Agricultural productivity in the region as a whole is likely to suffer losses because of high temperature, drought, floods and soil degradation, which, in turn, will put the food security of many countries under threat.

Livestock
Climate change in arid lands of the Region will result in less available soil moisture, exacerbating the current situation of the already degraded land. Rangelands are the dominant land type in the region, and as result of their extent, small changes in vegetation cover can significantly affect the organic carbon dynamics and storage in the ecosystem.

The livestock nomadic system spreads over a wide area with low and erratic rainfall, extending from the dry and low rainfall rangelands in the Near East and the Arabian Peninsula to the high rainfall areas (more than 1 200 mm) in southwest and southern Sudan. It is in this area that a further decline in available moisture is expected, resulting in an overall decline in productivity.

In temperate areas, temperature increases may lead to an increase in pasture production in mid-latitudes, with corresponding increases in livestock production. In general, un-housed livestock are expected to benefit from warmer winters, particularly at higher elevations, with minor improvements in feed quality in temperate high-rainfall zones possible. However, greater summer heat stress is likely to occur with negative effects on animals.

Livestock pest and disease distribution and their transmission patterns will be altered, with epidemics being almost certain.

Forests

In the Region, the majority of forest products are used for subsistence and in support of small-scale, household-based enterprises that provide income and employment for rural people, especially women. Despite their importance for local economies and livelihoods, forest products in the region remain largely neglected in the policy and decision-making processes of natural resource management.

A depletion of soil moisture may cause the productivity of major species to decline, increase fire risk and change the patterns of the Region's main pests and diseases. Modification of the habitat will subsequently induce changes in the wildlife population.

Fisheries

The region has a vast coastal area and several rivers with good potential for fishing. The region has become a net exporter in the fisheries sector, but its global share of trade is marginal, accounting for only about USD135 million in 1999. According to the IPCC, many basins already suffer from a lack of water. These basins are located, among others, in Africa, the Mediterranean region and the Near East.

It is extremely difficult to predict how climate change may affect fish stocks and the fishing industry, particularly in the context of the present stresses on fish stocks. While higher ocean temperatures may increase growth rates of some fish, the reduced nutrient supplies that result from warming may limit growth. Ocean acidification is likely to be particularly damaging.

According to the AR4, effects on macrophyte communities and the spread of warmer water species due to increased temperatures have already been observed in the Mediterranean, as have changes in populations, recruitment success, trophic interactions and migratory patterns of fish populations.

Adaptation to climate change

Looking at FAO data on actual arable land in use and irrigated areas from the mid-1990s, a rather diverse picture emerges for different countries. For example, while Algeria and Iraq probably still have potential to expand agricultural areas (Algeria has 61 percent of potentially arable land actually in use; Iraq has 75 percent), others countries such as Yemen and Saudi Arabia already utilize all their potential arable land as they have expanded into marginal lands.

Most countries have no or very limited rainfed cropping potential (Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates and Yemen all have less than 5 000 ha). Irrigation is used extensively but may cause problems in terms of groundwater recharge. Many countries seem to be using their full rainfed and irrigation potential already.

According to FAO projections, developing countries account for 75 percent of global irrigated land and are likely to expand their irrigated area until 2030 by 0.6 percent/year, while the annual cropping intensity of irrigated land will increase from 1.27 to 1.41 crops/ha, and irrigation water-use efficiency will increase slightly. These estimates do not take into account climate change. Most of this expansion is projected to occur in already water-stressed areas, such as southern Asia, the Near East and North Africa.

In the forestry sector, there are expanses of degraded land that could be reforested if grazing is controlled. Planted forests may help to counteract negative effects of climate change on natural forests and improve local water cycles. Some countries in the region such as Kuwait, Oman, United Arab Emirates and Egypt are building solid experience in afforestation and reclamation of desert areas, using sewage water for irrigation.

In the agriculture sector, a number of adaptation measures will provide win–win opportunities for climate change adaptation and sustainable agriculture:

- improved fertilizer use – nitrous oxide released into the atmosphere is a loss and an indication of inefficient farming;
- improvements to crop water management and productivity – development of water harvesting, conservation techniques, etc., aids adaptation to rainfall variability;
- improved rice farming – higher yields are accompanied by reduced methane emissions;
- increased use of conservation agriculture – improves soil carbon storage (sink) and soil structure, and increases waterholding capacity;
- improved low-impact harvesting in forests and better soil protection;
- increased large-scale plantings of perennial crops – although limited in the region due to insufficient water availability (except in areas where irrigation is possible), there are several pine species, tamarind, citrus, almonds and several acacias that sequester carbon and protect soil and sloping lands, thereby offering an economic buffer against soil degradation and mitigating impacts;
- substitution of bioenergy and fossil fuel – although a possible option, potential adverse effects on food security and the environment should be carefully assessed before any large-scale developments are put in place.

Mitigation of climate change

Historically, the RNEA has not been a significant source of GHG emissions. In 2004, the Near East (Middle East in Figure 2.18) accounted for 3.8 percent of global GHG emissions, and Africa, 7.8 percent. However, the Near East, together with North America and Asia, has been identified as the driving force in the rise in emissions since 1972.

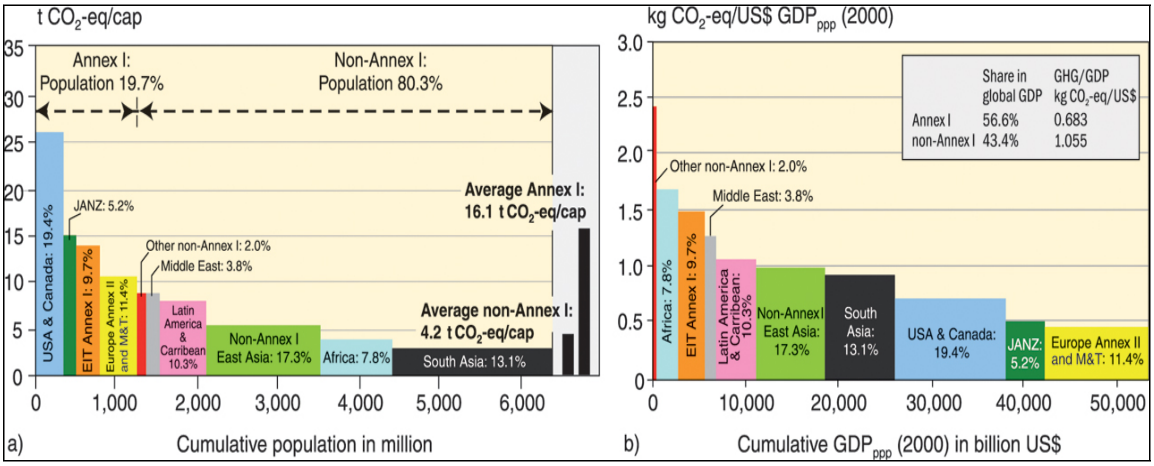

Figure 2.18 Regional distribution of GHG emissions: (a) distribution of regional per capita GHG emissions according to the population of different country groupings in 2000; (b) distribution of regional GHG emissions per USD of GDP (PPP) over the GDP of different country groupings in 2000
Source: Figure 2.2 in IPCC, 2007a.

Agriculture, forestry and fisheries sectors have multiple roles in the discussion of climate change. They are one of the first and hardest to be affected by climate change, while they account for one-third of total GHG (Figure 2.19).

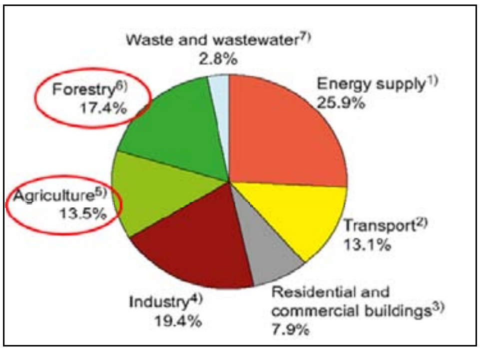

Figure 2.19 Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO_2-eq
Source: Figure 2.1 in IPCC, 2007a.

This in turn suggests that agriculture has great potential to contribute to mitigating climate change by reducing emissions through avoided deforestation and forest degradation and by sequestering carbon in soils.

Conclusion

The RNEA is likely to be adversely affected by climate change in multiple sectors that directly define the well-being of the population. Several areas for action constitute opportunities for the countries in the Region. Promotion of agriculture is key in the reduction of atmospheric GHGs, through building the capacity of agricultural personnel and decision-makers. Efforts to mitigate climate change and to enhance the resilience of rural populations and their livelihoods to climate variability and climate change impacts can be considered in line with efforts to achieve higher levels of sustainability. Agricultural practices that reduce GHG emissions or sequester carbon and help farmers to adapt to climate change at the same time should be identified and promoted, contributing to sustainable development.

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Annex – Climate change impacts and vulnerability of the countries of the Near East and North Africa Region

Vulnerable sectors and possible impacts of climate change identified in national communication reports under the UNFCCC are listed. Common climate-related disasters are identified based on the database of the Centre for Research on the Epidemiology of Disasters (www.emdat.be/database). The disasters in the database are listed according to the number of people affected. For the most recent disaster, the year of occurrence is also given. Only the most important ten recent disasters are taken into account.

Country	Vulnerable sectors and possible impacts of climate change	Common climate-related disasters
Algeria	Vulnerable to natural hazards such as floods and drought.	Floods (1969)
Bahrain	Low-lying areas of the country's islands vulnerable to sea-level rise.	None
Egypt	Reduced productivity of crops and increased water requirements. Heavily populated Nile Delta vulnerable to sea-level rise.	Floods (1994), windstorms
Iran (Islamic Republic of)	Change in length of growth period and number of freezing days. Damage from intense cyclones originating in Arabian Sea.	Drought (1999), floods
Iraq	Possible impacts on Tigris–Euphrates stream flow. Increasing irrigation demand.	Drought (1969), floods
Jordan	Increasing irrigation demand. Possible rainfall decrease adds additional stress to already scarce water resources.	Drought (1999), floods, windstorms, high temperatures
Kuwait	Low coastal areas vulnerable to sea-level rise. Storm surges affect coastal oil production.	Floods (1997)
Lebanon	Increased stresses on water resources. Shift of arable area to more arid climate zone. Negative impacts on citrus, olive, apple and sugar-beet production.	Windstorms (1992), floods
Libyan Arab Jamahiriya	Recurring droughts and dependence on rainfed agriculture. Possible desertification of Jifara Plain in northwest.	None
Mauritania	Decreased water resources. Dependence on water originating outside border. Degradation of arable land. Degradation of pasture and loss of livestock.	Drought (1980), floods
Morocco	Ouergha watershed will likely see changes in runoff.	Drought (1999), floods
Oman	Seawater intrusion into freshwater aquifers. Storm surges affect coastal oil production. Decreasing groundwater level.	Windstorms (2007)
Qatar	Increasing water stress. Storm surges affect coastal oil production.	Not available
Saudi Arabia	Water stress will increase due to warmer temperature.	Floods (2003), windstorms
Syrian Arab Republic	Possible impacts on Tigris–Euphrates stream flow. Increasing irrigation demand.	Drought (1999), floods, windstorms, landslides
Tunisia	Mediterranean coast vulnerable to sea-level rise. Increased water stress.	Floods (1979), drought
United Arab Emirates	Seawater intrusion into freshwater aquifers. Storm surges affect coastal oil production.	None
Yemen	Risk of desertification. Increasing irrigation demand.	Floods (1982), drought

2.2 Adapting to climate change: the ecosystem approach to fisheries in the Near East and North Africa Region

Introduction

The IPCC projects that atmospheric temperatures will rise by 1.8–4.0 °C globally by 2100 (IPCC, 2007). This warming will be accompanied by rising sea temperatures, changing sea levels, increasing ocean acidification, altered rainfall patterns and river flows, and higher incidence of extreme weather events (WorldFish Center, 2008).

The productivity, distribution and seasonality of fisheries, and the quality and availability of the habitats that support them, are sensitive to these climate change effects. In addition, many fishery-dependent communities are in coastal and riparian environments and highly exposed to climate change. Therefore, the impacts of climate change on fisheries are not only limited to the production sector but extended to the social and economic aspects of fisheries communities.

Many capture fisheries worldwide have declined sharply in recent decades or have already collapsed from overfishing. Climate change will compound existing pressure on fisheries. How to sustain fisheries in the face of climate change poses a great challenge to fisheries management. Due to the extensiveness, complexity and unpredictability of climate change impacts, a holistic approach must be adopted when developing coping policies and mitigation measures. The EAF (FAO, 2009) provides a framework for integrated management of fisheries, taking into account the knowledge and uncertainties in biotic, abiotic and human components of ecosystems and their interactions. The holistic nature of EAF provides the most comprehensive approach to tackling the issues of climate change impacts on fisheries.

This paper first presents a brief overview of the EAF – its background, principles and processes for application – and then provides preliminary thoughts on the role of the EAF in identifying vulnerability of fisheries to climate change and in developing policy and strategies to address climate change impacts. Much of the introductory information on the EAF has been abstracted from FAO (2009) and Bianchi, Cochrane and Vasconcelos (2009).

FAO's ecosystem approach to fisheries

Institutional foundation

The EAF emerged from the convergence of two important paradigms: conservation, and fisheries management. Conservation focuses on the protection of the natural environment; whereas, fisheries management mainly aims to harvest a resource sustainably to meet societal and economic needs. Supported by the concept of sustainable development, the EAF builds on the recognition of the interdependence between ecosystem health and human well-being. The approach is also motivated by the increased understanding of fishery–ecosystem interactions and by the poor performance of conventional fishery management approaches. The principles, concerns and policy directions contained in the provisions of the Code provide a framework for the EAF.

Hence, the concepts and principles of the EAF are not new. They are contained in a number of international instruments, agreements and conference outputs, in addition to the Code, that have been negotiated during the last few decades. The two main international roots of the EAF – as well as the Code – are the 1972 Declaration of the United Nations Conference on the Human Environment (the "Stockholm Declaration") and the United Nations Convention on the Law of the Sea (UNCLOS) adopted in 1982. In 1992, the United Nations Conference on Environment and Development (UNCED) emphasized both the importance of placing people at the centre of concerns and of the sustainable exploitation of resources. The Rio Declaration on the principles of sustainable development, and Agenda 21, which contained extensive provisions for the seas and oceans and their management, were adopted in 1992. The Convention on Biological Diversity (CBD) was also signed, elaborating the core principles of multiple-use biodiversity management and leading to the adoption in 1995 of the EA as the primary action framework under the CBD. A number of international events have followed, including the adoption of relevant United Nations General Assembly (UNGA) Resolutions (e.g. 61/105 and 61/222), which have contributed to the progressive emergence of the EAF and related paradigms.

Linked to the United Nations (UN) and international agenda are a myriad of national and regional efforts and initiatives to apply a more holistic approach to fisheries management and to safeguard ecosystems. Parallel initiatives also exist within other sectors, such as forestry and tourism; all contributing to international efforts toward sustainable development approaches and practices. In the context of oceans, examples of cross-sectoral approaches include: ecosystem-based fishery management (EBFM), implemented by, for example, the United States Pacific Fisheries Management Council; the ecosystem approach to management (EAM) undertaken by the Commission for the Conservation of Living Marine Resources of the Antarctic Region (CCLMRAR); the fisheries ecosystem management framework contained in the Australian national strategy on ecologically sustainable development (ESD); and the LME management initiatives. There are similarities in the

overarching principles and objectives of the various approaches to natural resource management, but there are also differences in their scope and emphasis.
The EAF is also closely linked to other approaches in the field of development, natural resource and spatial area management, e.g. the sustainable livelihoods approach (SLA) and integrated management (IM). These approaches are complementary to the EAF, and indeed there is a substantial overlap in terms of their underlying principles, philosophy and methods.

Principles and definition
The EAF takes its focus in fisheries management but broadens the perspective beyond seeing a fishery as simply “fish in the sea, people in boats”, beyond consideration only of commercially important species, and beyond management efforts directed solely at the fish harvesting process. The EAF requires the inclusion of interactions between the core of the fishery – fish and fishers – as well as other elements of the ecosystem and the human system relevant to management. The EAF is aligned with the more general EA but is mainly bounded by the ability of fisheries management to implement the EA(F). However, this should not be seen as downplaying the fisheries sector’s responsibility in collaborating in a broader multisectoral application of the EA:

- The purpose of an EAF is to plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by the aquatic ecosystems.
- An ecosystem approach to fisheries (EAF) strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries (EAF Guidelines, page 6).

Table 2.2 Moving towards an EAF – examples of the shifting focus

Conventional fisheries management	**EAF**
Stakeholders are those directly or indirectly involved in fishing activities	Stakeholders are found throughout the fishery system and in other sectors of the ecosystem
Management commonly by government fisheries authority (top-down)	Participation and comanagement with a broad spectrum of stakeholder groups
Operates through regulations and penalties for non-compliance	Compliance with regulations is encouraged through incentives
Single-species (or target-resource) management	Target and non-target species, habitat and broader ecosystem impacts
Focus on the fishery	Focus on the broader fishery system
Indicators related to fish catches and status of fish stock	Indicators related to all parts of the aquatic ecosystem and goods and services
Scientific knowledge is the only valid knowledge for decision-making	Traditional, local, and scientific knowledge systems may be used for decision-making

The EAF is not inconsistent with or a substitute for conventional fisheries management approaches but intends to improve their implementation and reinforce their ecological relevance with a view to contributing to achieving sustainable development. Accordingly, an EAF should address the following principles:

- Governance should ensure both human and ecosystem well-being and equity.
- Fisheries should be managed to limit their impact on the ecosystem to the extent possible.
- Ecological relationships between the fishery resources targeted and harvested by a fishery and those species dependent and associated with these resources should be maintained.
- Management measures should be compatible across the entire distribution of the fishery resource, i.e. in the whole area where it exists, including across jurisdictions and management plans if required.
- The precautionary approach should be applied because the knowledge on ecosystems is incomplete.

Hence, the EAF is an extension of the conventional fisheries management paradigm[2] allowing for a broader and more holistic approach to analysis and management actions. In conceptual terms, this may appear fairly clear. However, in practice, the exact shape and magnitude of this extension will vary from one situation to another as existing fisheries management systems range widely from basically free and open access to more elaborate multispecies and/or rights-based management frameworks. Table 2.2 provides some examples of the shift in focus that EAF entails.

The EAF in practice

The EAF process

The typical EAF process has been described in the EAF Guidelines produced by FAO, and the various concepts and mechanisms are pulled together here with a focus on how to operationalize an EAF. While recognizing that the paths into an EAF vary and that the process is iterative, the planning and implementation of an EAF follow Figure 2.20 and five main steps:

- initiation and preparation;
- formulation of an EAF policy and identification of issues;
- development of a management plan and operational objectives;
- implementation;
- monitoring and evaluation.

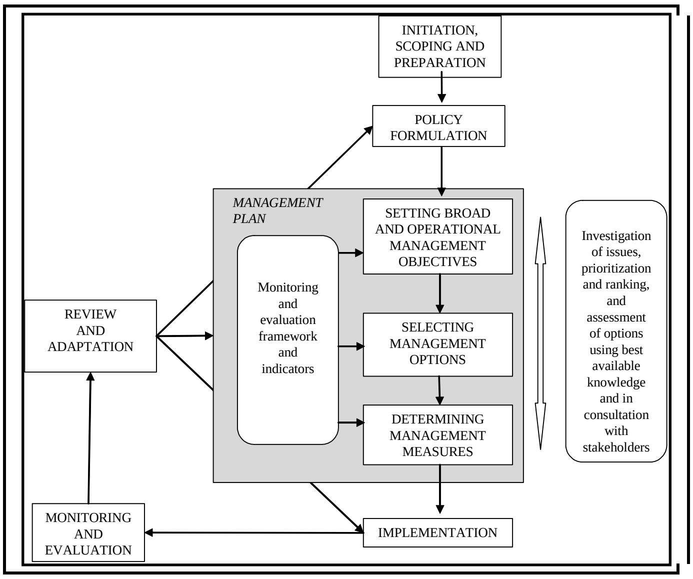

Figure 2.20 Steps in the EAF process

Initiation and preparation

Whatever the path into an EAF is, and independent of the existing fisheries management situation, the first activities of any EAF process will concern planning and preparation. The purpose of this first step is to gather initial information and to plan a participatory process consistent with the context (cultural, resources available, types of fisheries, etc.). It will also include the definition of the scope

[2] In medium- and large-scale commercial fisheries, the dominant fisheries management paradigm in recent decades has been so-called target-resource-oriented management (TROM), focusing mainly on the stock of the target species. However, many small-scale, multispecies fisheries are undertaken with little intervention beyond development support, or are based on more traditional management systems. The term "conventional fisheries management" will be used in this paper referring to the global situation, of which TROM is a part.

and scale of the EAF, and the development of a common understanding of what the current situation is and what the potential issues are.

An EAF can be initiated at a variety of levels and by different stakeholder groups. However, the responsibility for coordinating and implementing the EAF generally remains with the competent fisheries management authority. The EAF coordinators will need to establish an initial EAF process plan and ensure that the necessary basic resources for carrying out the process are available. Human resources are a key element and the EAF team should have the necessary multidisciplinary and technical capacities as well as the ability to bring about collaboration with partners and stakeholder groups. This means constructing an EAF team consisting of scientists and practitioners including, *inter alia*, sociologists, anthropologists, economists and biologists, preferably with interdisciplinary capacities. There is also a need for process-oriented skills such as facilitation, negotiation and change management. It is important to ensure that all relevant disciplines are integrated in the process, i.e. for planning and preparation, policy formulation and identification of issues, management plan development, implementation, and monitoring and evaluation. The formal integration of all EAF disciplines will reduce the cost of management and make the EAF process more effective than if they are kept separate.

There may also be a need to establish a specific mechanism for intersectoral coordination. Depending on the scope and scale of the EAF and on the composition and mandate of the EAF team, an intersectoral advisory group or committee could be needed to support and coordinate the work at a higher political and administrative level. Such a group or committee would include representatives from relevant government agencies as well as key non-governmental organizations (NGOs) and the private sector.

The identification of stakeholders – by conducting a stakeholder analysis – is a key activity at the beginning of the EAF process. This exercise will widen the group of individuals, organizations and agencies that should be consulted and involved beyond the EAF team and immediate partners. Further along the EAF process, these stakeholder groups may expand or change. Establishing rules and institutional structures for how different stakeholders engage and participate in the EAF is fundamental for its implementation.

It is also critically important to ensure that there is a common understanding among stakeholders of what the EAF means in the context of fisheries management, so that policy and management measures that are subsequently developed are informed by the underlying concepts. The EAF plan needs to have clear objectives and should define the EAF principles that it is based on. In conjunction with defining the scope and scale of the EAF, the coordinators have to be clear about what they intend to achieve and ensure that this view is shared with key stakeholders and the EAF team members. Early on in the process, this perspective should be communicated and discussed with the wider group of stakeholders and the public. It is likely that efforts and resources will have to be allocated to raising awareness and building capacity as part of the EAF communication strategy.

Initial stakeholder consultations should identify main societal goals and the interests and objectives of different groups. These should be shared, recognizing that the perceptions and aspirations of different groups may sometimes appear difficult to reconcile and require repeated facilitation and negotiations. Once it is understood that a reconciliation of views is required , objectives can be developed into a common vision for the EAF. A vision is a description of the ideal state of the fishery and its ecosystem that stakeholders aspire to, both in terms of its biological status and their socio-economic circumstances and governance arrangements, and it constitutes a basis for policy formulation.

A “scoping exercise” is another element of the initial preparatory phase. This entails a preliminary collection and consolidation of basic information on the fishery system and the related ecosystem as defined by the agreed scope and scale of the EAF. At this stage, a background document that can be expanded and elaborated on further is required; this will help the EAF team to understand the potential critical issues that the EAF should deal with. The issues and concerns identified in the consultative process should also be taken careful note of and will together with the vision form the basis for developing an EAF policy and, subsequently, a management plan.

In summary, the outputs of the EAF "initiation and preparation" step are an EAF team, a detailed process plan, a preliminary mapping of stakeholders, plans for participation and communication, a draft scoping document (i.e. a summary of the nature of the fishery system and its context) as well as an initial list of potential issues and a vision statement.

Identification of priority issues and formulation of an EAF policy

This step comprises a further elaboration of the preliminary scoping exercise and the definition of policy options and goals. However, in most cases, the move towards an EAF is incremental and is unlikely to involve wholesale scrapping of existing policies and management frameworks. Although it may be appropriate and desirable to formulate entirely new policies in some cases, it is more likely that there will be a gradual review and modification of existing policies.
The setting of goals requires input from all relevant stakeholder groups and is informed by an analysis of the information collected on the fishery system, its policy, institutional and legal frameworks and socio-economic context. The issues identified in the preparatory phase and the vision statement provide the general framework for the policy formulation. The process for identifying goals will vary depending on the scale of the EAF (e.g. LME versus local level) and may require several iterations to ensure that the goals identified do in fact represent stakeholders' priorities. There will also be a need for continual reference to the EAF principles to ensure conformity. It should be recognized that the setting of priorities will also be influenced by other factors, such as the macroeconomic policies of the country, the particular focus of the current political regime or commitments that have been made in terms of international agreements or conventions.

Typical policy level goals could include statements relating to fishery rights and access (management and use rights), priorities given to different fishery subsectors or the role the fisheries sector should play, for example, economically or for creating employment opportunities – locally or in the region – and, of course, outline biological and ecological goals with regard to desired states of fishery resources or ecosystems. At times, the existing legal framework may not support the policy change that the EAF entails. In such cases, EAF coordinators have to investigate the possibilities of revising relevant legislation.

The output of the policy formulation process will be a policy document. This document should be made available to all stakeholders and the public in general in order to ensure transparency. It should also be remembered that policies are not static instruments but need to be reviewed regularly, incorporating relevant developments and experiences gained.

Development of an EAF management plan and its objectives

The EAF management plan provides a mechanism to support the implementation of desired policy directions. Thus, while the policy level is strategic in nature, a management plan is at the practical level of specifying the objectives and actions needed to achieve the broad goals of a fishery or an associated ecosystem which, in turn, provide the inputs into the subsequent operational aspects of implementation. The development of the management plan is a key step in the EAF process and will include the setting of management objectives, selecting management options and determining management measures (see Figure 2.20). The management plan should also contain indicators and performance measures and outline monitoring, assessment and review processes.

An EAF management plan is designed along similar lines to a management plan that might be developed within a government department, NGO or private business in order to meet policy goals. The essential idea is also similar to that of a conventional fisheries management plan, but the suite of fisheries management tools proposed in an EAF management plan should be explicitly linked to the principles and practice of the EAF.

Generally, the stakeholder analysis carried out as part of the initial preparations would need to be refined at this stage. It is also advisable to identify a few individuals who could represent the interests of larger stakeholder groups, and who would interact with the EAF managers on an ongoing basis. Special attention should be given to ways of identifying and involving poor and marginalized groups and individuals who may not respond to mainstream announcements of opportunities for public involvement. Including poor and food-insecure fishers and fish workers in the management processes is likely to improve the potential for pro-poor content of the EAF and address potential inequitable distributional effects. There may be a need to provide capacity building and training to ensure that all stakeholder groups have equal opportunities to participate in the EAF.

Management-level objectives are more narrowly expressed than policy goals and are generally defined at two levels: broad management objectives, and operational objectives. The broad objectives state the intended outcomes of the EAF management and constitute the link between the policy goals and what a specific EAF management is trying to achieve. The operational objectives are more specific and have direct and practical meaning for the fishery system that is being managed. They should be measurable and linked to specific time periods.

The real challenge is not simply to list all objectives but to prioritize them in order to reflect the reality of limited resources and the fact that some objectives will be considered more important than others. In order to do so, there is a need to further investigate and prioritize the underlying issues and concerns. This may involve simply providing a consolidated list of all issues raised and grouping them under common headings, with a brief description of all the issues based on currently available information. However, more often, investigations should involve follow-up discussions with stakeholder groups. In order for stakeholders to make informed judgements regarding priority issues and which of the available options might best serve societal needs and goals, information about their potential impact (e.g. effectiveness and distribution) and other consequences (e.g. costs/benefits and political implications) needs to be gathered and made available. There are various methods that can be used to assist in this process and the approaches for assessing costs and benefits and associated risks, as described in De Young, Charles and Hjort (2008), are useful tools in this respect.

To achieve the objectives, choices have to be made regarding the specific EAF management tools to be used. These measures can include technical measures (e.g. gear regulations), spatial and temporal controls (e.g. marine protected areas [MPAs] and closed seasons), and input (effort) and output (catch quota) controls as well as incentives and other mechanisms. In deciding which measures and instruments to use, the impacts and effectiveness of the different options need to be assessed and analyses of costs and benefits is a key approach here. For example, suppose that a policy decision has been made to adopt a participatory comanagement approach in a particular fishery. While there are clear benefits to this approach, there are also likely to be cost implications in terms of time and expense. Decisions may have to be made in the context of the management plan to determine a specific form of participatory comanagement that achieves a desired balance among these costs and benefits. Depending on the specific context, some options being considered for a management plan may turn out to have excessively large cost implications whatever the potential benefits (e.g. implementing a multispecies quota system, as a means to deal with bycatches and species interactions, may be financially infeasible in many circumstances), while other options might be seen as “win–win” options (e.g. using a suitably inexpensive device to reduce unwanted bycatch while simultaneously reducing fishing costs).

The distributional implications of a management option are additional key factors to consider. In some cases (e.g. the establishment of certain MPAs), the aggregate benefits may clearly outweigh the costs, but the distributional impacts of the measure may be a critical issue, i.e. inequities in impacts across stakeholders, with some benefiting greatly while others incur a disproportionate fraction of the costs.

As it is likely that there will be divergent stakeholder interests, it is inevitable that hard choices will have to be made, and key issues that often arise are: (i) Who ultimately determines which objectives and management options are the preferred ones?; and (ii) What are the criteria that ultimately inform such choices? In order to arrive at an effective management plan, compromises often have to be made. In fact, it is likely that there is no optimal route satisfying everybody's wishes, but "second best" – for everyone – management options may be the solution. In order to arrive at acceptable compromises, extensive negotiations may be required, combined with facilitation methodologies, e.g. scenario exercises and analyses of risks and uncertainties. If consensus cannot be reached, the decision-makers may need to call in a skilled negotiator or they may decide to make the final choices without further reference to the participatory process. However, care should be taken not to ignore any minimum requirement defined by stakeholder groups when settling for a "second-best" management option.

In addition to specifying management measures, it is fundamental that the management plan includes the necessary institutional details for implementing the EAF processes that have been chosen. It also has to be ensured that the preferred management options are supported by the existing legal framework. For example, if a policy decision were made to involve stakeholders in management, then the management plan would need to clarify the degree of such comanagement, the roles and responsibilities of the participants and guidance for the institutional structure and functioning. The legal framework needs to allow for delegation of management authority to comanagement groups. If not, it will be difficult to implement the management plan until a legislative revision has taken place.

Implementation

The management plan specifies choices of management options and management measures that are considered suitable to achieve the objectives set at the beginning of the process – objectives for management that build on broader policy goals and indeed overall societal goals. Once the various choices have been made, there remains the challenge of implementation.

While in conventional fisheries management practices, implementation may have been carried out by the government fisheries agency alone, EAF management generally involves a broader institutional setup including collaboration with parties outside the fisheries sector. Even within the fisheries sector, the stakeholder groups are likely to be more numerous and diverse, and this reality may require a review of the institutional structure. Owing to the broadening of the management scope, support from higher levels within the national administration and political arena – and from other partners, e.g. NGOs and private sector – for coordination and provision of the resources necessary for implementation will be desirable. A need for capacity building and training of staff should be expected in order to ensure a thorough understanding of the EAF concept.

As with the other steps discussed in the EAF process, the implementation details will be situation-specific, but successful EAF implementation is likely to depend on:

- political commitment;
- appropriate legal and institutional frameworks that enable practical implementation;
- capacity and skills, both with regard to human resources and equipment;
- cooperation across relevant sectors and departments;
- ongoing stakeholder support;
- appropriate funding, especially when substantial new processes and systems need to be established.

In practice, some of the tasks to be performed by the EAF managers and other staff may be similar to those carried out previously where a conventional fisheries management plan had been in place. When developing a detailed EAF task implementation plan, a careful review should be carried out considering what needs to change, what additional tasks need to be undertaken and what no longer needs to be done. Difficult choices may be needed, particularly in an environment of limited resources. The roles and responsibilities, as well as the resources needed for undertaking each task and activity, should be clearly identified. Operational plans for each partner or group, e.g. research group, compliance group, and information management unit, should be put in place. Procedures and systems need to be updated according to the new EAF management and implementation plan.

Similarly, the monitoring, control and surveillance (MCS) functions need to be reviewed and changed as required. These will depend on the scope of the EAF and the management measures that are used, as is also the case under conventional fisheries management practices. However, the EAF will address a wider scope of ecosystem elements and may also use a wider range of management measures. Observer schemes (e.g. for bycatch and discard monitoring), vessel monitoring systems (VMSs; e.g. for control of closed areas and MPAs) and means for patrol and enforcement are examples of possible MCS components.

Communication and transparency are key aspects of EAF operational implementation. Information on the development of the fishery and its EAF management system has to be made available and communicated to all directly concerned. Although the fishing industry and fishers will have been involved in the participatory process of establishing the EAF management plan, there will still be a need for meetings and information sharing with all relevant parties.

Monitoring and evaluation

An EAF requires a suitably integrated and interdisciplinary approach to monitoring and evaluation, and a system for review and adaptation needs to be built into the process. Depending on the particular situation and local conditions, the monitoring and evaluation package will vary from one EAF to another. There are a number of different approaches that can be used, including participatory methods and performance indicators. Indicators and reference points are commonly at the core of a monitoring system and should be defined within an overall framework that will allow for adaptive management.

While monitoring and evaluation are essential aspects of any fisheries management system, there are particular challenges in EAF management, owing to the increased scale and scope involved. In other words, it becomes necessary to monitor not only the narrow aspects of a specific fish stock and the fishers exploiting it, but also the state of the aquatic ecosystem, interactions with and impacts on other uses of that ecosystem, and relevant human dimensions, including the dynamics of fishers, fishing communities, and the surrounding socio-economic environment. Furthermore, both the scope and the criteria for evaluation must be broadened to allow for the reality that additional objectives, both ecosystem-oriented and multiuse related, are being pursued.

There are many different criteria and types of indicators that may be of interest within an EAF framework. The policy document and management plan should specify indicators and reference points for all goals and objectives. These will hence range from reflecting broader sustainability issues at the policy level, e.g. social, economic and institutional targets derived from the Millennium Development Goals (MDGs), to more basic measures of fish catches and exports, fishery employment and revenues, and fishing community welfare, as well as attributes such as ecosystem health and community resilience. It is also desirable to include performance monitoring in the management plan, including process-based indicators for assessing the quality of implementation. The outcome-based indicators should be related to the impact of the fishery, so that its value is altered if the fishery impact changes.

Indicators should deliver meaningful information on results, achievements and performance. They need to be based on data and the means for collecting information, and the cost implications should be taken into consideration when designing the monitoring system. If a large number of indicators are suggested, reflecting the priorities of different stakeholder groups, these need to be assessed and a selection made as to which are the most pertinent ones. Particularly in data-poor situations, the number of indicators should be restricted to a few effective ones based on defined criteria.

Monitoring and review should take place at regular intervals to systematically compare the current situation and what has been achieved to date, with the reference points defined for each indicator. An EAF would typically include both continuous monitoring, short- and long-term review and evaluation cycles. The monitoring and review/evaluation processes should include mechanisms for reassessing and redefining policy goals and management objectives and measures as required in accordance with the adaptive management approach.

The EAF and climate change

Potential impacts of climate change on fisheries
Climate change has a strong impact on fisheries and aquaculture, with significant food security consequences for certain human populations. Such impacts have already been observed in many circumstances and include:

- In marine waters, climate processes and extreme weather events will increase in frequency and intensity – the most well known of these is the El Niño phenomenon in the South Pacific.
- The ongoing warming of the world's oceans is likely to continue, 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 fish distributions in response to climate variations have already been observed, generally involving pole-ward expansions of warmer-water species and pole-ward contractions of colder-water species.
- Shifts in ocean salinity are occurring, with near-surface waters in the more evaporative regions of most of the world's oceans increasing in salinity, while marine areas in high latitudes are showing decreasing salinity owing to greater precipitation, higher runoff, melting ice and other atmospheric processes.
- The oceans are becoming more acidic, with probable negative consequences for many coral reef and calcium-bearing organisms.

However, the consequences and extent of the impacts of climate change are difficult to predict or quantify. To maintain the long-term sustainability of fisheries, there is a strong need to develop an effective and flexible fisheries management system in an ecosystem context and to adopt a precautionary approach.

Using the EAF to identify key climate change issues
A key step in the EAF process described above includes the identification of issues (and their prioritization) that need to be addressed by management. To assist in this process, FAO has adopted the ESD issues identification trees that help to identify the specific issues to be managed in the EAF process, including all direct and indirect impacts of the fishery on the broader system. Included in this step is the identification of any non-fisheries issues (those that are external to the fisheries management system) that are affecting, or could in the future affect, the performance of the system and its management.

Figure 2.21 presents generic trees that may be used as starting points for issue identification for a particular fishery or operating unit (OU). To aid in identifying issues in line with the EAF, a three-branched tree is usually proposed: 1. ecological well-being; 2. human well-being; and 3. ability to achieve. The third branch comprises all governance[3] aspects and all extra-fisheries aspects. Climate change naturally finds itself as an issue here as well as impacts on the system from other aquatic and coastal resource users, impacts of changes in prices, and other social, political and economic aspects affecting the fisheries but outside the direct mandate of fisheries management.

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[3] Governance is interpreted as the formal and informal arrangements, institutions and mores that determine how resources or an environment are utilized; how problems and opportunities are evaluated and analysed, what behaviour is deemed acceptable or forbidden, and what rules and sanctions are applied to affect the pattern of resource and environmental use (Juda, 1999).

Using the identification of biophysical changes due to climate change expected for the fishery/OU (e.g. changes to water surface temperature, pH levels, and sea level, extreme events), their impacts on the three branches can be identified in a systematic manner. The example shown in Figure 2.21 shows how biotic and abiotic changes identified are, for example, translated into impacts on the species under investigation (Branch 1). Impacts under Branch 2 could include issues regarding safety at sea or along the coasts, impacts on the profit structure of fisheries, and loss or no longer appropriate placement of infrastructure[4]. Impacts under Branch 3 could include increasing demands on the government to deal with fish and human migration issues and changes in the costs of fuel.

How these branches are filled in depends on the context at hand, but the process would allow for a systematic identification of issues and a means to prioritize management responses in the short and long terms. Having the broadened monitoring system that an EAF would imply would also help to monitor changes in the aquatic ecosystems, whether they are leading indicators that help predict likely future changes or indicators that identify current changes to the system. As noted below, FAO is developing a suite of indicators useful for monitoring changes affecting fisheries systems.

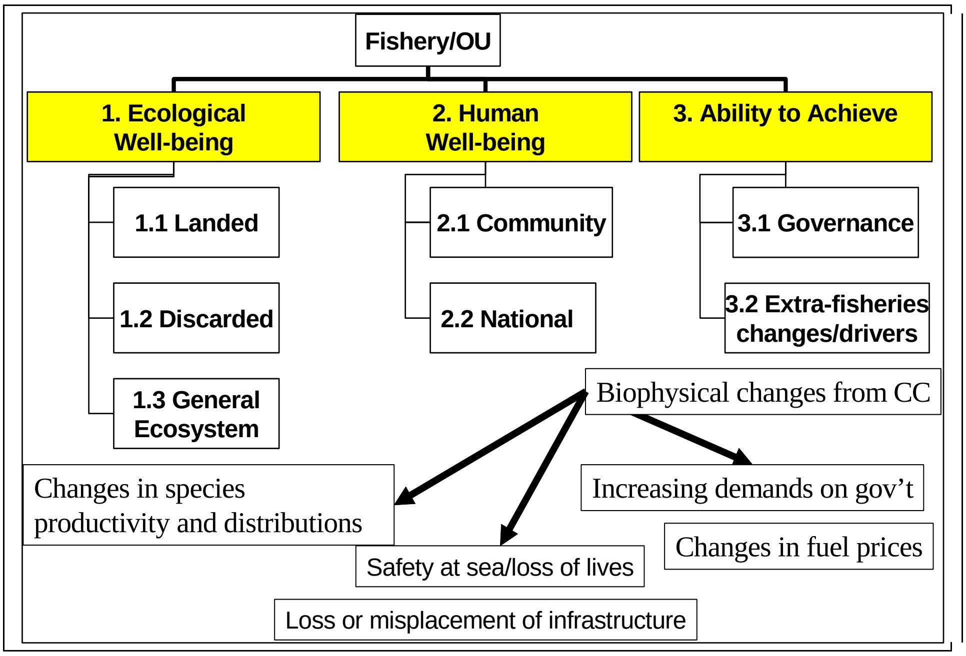

Figure 2.21 Using the EAF issue identification process to identify climate change impacts

Using the EAF to address climate change

Mitigation (increased sequestration and decreased emissions)

Fisheries activities make a minor but still significant contribution to GHG emissions during production operations and the transport, processing and storage of fish and fish products. The primary mitigation route for the sector lies in its energy consumption, through fuel and raw material use and through the responsible management of distribution, packaging and other supply chain components. Fuel efficiency for the sector as a whole can be improved by EAF management – current overcapacity and excess effort lead to lower catches per unit effort and, therefore, lower fuel efficiency. The EAF would reinforce the sector's move to environmentally friendly and fuel-efficient fishing and to eliminating subsidies that promote overfishing and excess fishing capacity. The EAF lends itself as the approach to attain these mitigation goals by directly promoting improved governance, innovative technologies and more responsible practices that generate increased and sustainable benefits from

[4] An example of such is occurring in Namibia, where, owing to shifts in population distributions, processing plants are now finding themselves 100 nautical miles displaced *vis-à-vis* the stocks, having obvious impacts on their profitability.

fisheries. In addition, the EAF will help to eliminate any negative impacts the sector may have on the role of aquatic systems as natural carbon sinks.

Adaptation

To build resilience to the effects of climate change and to derive sustainable benefits, fisheries and aquaculture managers, as a top priority, need to adopt and adhere to best practices such as those described in the Code and the EAF. Progress in this direction would be an important contribution to maintaining biodiversity, preserving the resilience of human and aquatic systems to change, and improving capacity to anticipate and adapt to inevitable climate-induced changes in aquatic ecosystems and the related fisheries production systems. Some direct potential benefits of implementing the EAF include:

- creating a resilient ecosystem, human and governance communities and decreasing vulnerability to change through decreasing the impacts to the sector, decreasing the communities' sensitivities to change and increasing the sector's adaptive capacity;
- supporting intersectoral collaboration (e.g. integrating fisheries into national adaptation and disaster risk management [DRM] strategies and supporting integrated resource management);
- improving general awareness of climate change within and outside the sector;
- promoting context-specific and community-based adaptation strategies;
- avoiding "mal-adaptation" (e.g. overly rigid fishing access regimes that inhibit fisher migrations);
- allowing for quick adaptation to change;
- promoting natural barriers and defences rather than hard barriers that would affect the ecosystem.

Mitigation and adaptation – understanding synergies and trade-offs

As discussed above, there are many possibilities for mutually reinforcing synergies, and benefits exist among mitigation and adaptation actions within the sector and the sector's own development goals. In addition, the sector may benefit from synergies stemming from outside the sector, such as the inclusion of mangroves in the programme of the United Nations Collaborative Initiative on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD)[5] that should promote their conservation and provide positive spin-off benefits for fisheries, safeguarding the aquatic environment and its resources against adverse impacts of mitigation strategies and measures from other sectors.

There can be negative trade-offs between adaptation and mitigation. As noted in FAO (2008a), adaptation measures in one sector may negatively affect livelihoods in other sectors. For example, river fisheries can be negatively affected from adaptations in other livelihood sectors upstream. In particular, irrigation's additional water needs can reduce flows and affect seasonal spawning and fish productivity. Mitigation measures, such as fertilization of the oceans, can have unintended effects on marine ecosystem structure and functions.

The EAF and EA in general could reduce risks from these trade-offs by promoting diverse and flexible livelihood and food production strategies, flexible and adaptable institutions, food-security risk reduction initiatives and planned food-security adaptation to climate change (FAO, 2008a).

FAO in action

In addition to a series of Technical Guidelines (FAO, 1997, 2003, 2008a and 2008b) and Technical Papers (De Young, Charles and Hjort, 2008; Garcia *et al*., 2003; Plagányi, 2007), FAO's Department of Fisheries and Aquaculture is also in the process of developing a set of practical approaches and

[5] See www.undp.org/mdtf/un-redd/overview.shtml

methods in support of EAF implementation. It is expected that a first Web-based “EAF toolbox” will be made available and, furthermore, a detailed review of indicators useful for monitoring ecological, socio-economic and governance issues under an EAF will be completed and made available to the general public. In the meantime, some process methodologies and information management tools are included in De Young, Charles and Hjort (2008).

In response to FAO’s Member Countries’ requests for assistance in applying the EA, several trust fund projects are being implemented in FAO with the purpose of addressing the EAF through concerted efforts aimed at simultaneously achieving progress in several if not most of the relevant aspects of the EAF in selected locations or ecosystems. These projects are described briefly in the annex to this paper.

Regarding climate change activities, FAO’s Department of Fisheries and Aquaculture has formed an internal Working Group on Climate Change and has helped form the Global Partnership Climate, Fisheries and Aquaculture (PaCFA)[6], comprising 20 international organizations and borne from a mutual desire to draw together potentially fragmented and redundant climate change activities through a multiagency global programme of coordinated actions and the pressing need to raise the profile of fisheries and aquaculture in the UNFCCC negotiating process[7]. Strategic and programme frameworks are being developed both within FAO’s Department of Fisheries and Aquaculture and the PaCFA.

FAO’s Department of Fisheries and Aquaculture has recently published an overview of current scientific knowledge regarding climate change implications for fisheries and aquaculture (Cochrane *et al*., 2009) and will focus its near-term activities on:

- identifying fish production systems most likely to be impacted by future climate change;
- developing the baseline information and definition of indicators to monitor changes in aquatic ecosystem productivity and human well-being with respect to climate change;
- developing documentation on adaptive frameworks, mechanisms and best practices as well as Technical Guidelines on adaptive strategies in fisheries and aquaculture;
- creating awareness and outreach and developing capacity building;
- producing ongoing reviews of best available knowledge at various scales and regions;
- integrating climate change adaptation and disaster risk reduction planning to increase resilience in fishing communities;
- identifying emissions and mitigation potentials from fisheries and aquaculture and promoting their implementation.

[6] See www.climatefish.org/index_en.htm
[7] See, for example, ftp://ftp.fao.org/FI/brochure/climate_change/policy_brief.pdf

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Annex – FAO EAF projects

The project "Ecosystem Approaches for Fisheries Management in the Benguela Current Large Marine Ecosystem", a cooperation between FAO, the Benguela Current Large Marine Ecosystem (BCLME) programme and fisheries agencies of Angola, Namibia and South Africa, examined the feasibility of implementing the EAF in the Benguela region. This project pursued a structured and participatory approach based on the FAO Guidelines, to identify and prioritize the gaps in the existing approaches and consider potential management actions to address them.

"Scientific Basis for Ecosystem-based Management in the Lesser Antilles including Interactions with Marine Mammals and Other Top Predators" was another project that provided technical assistance to fisheries institutions of selected countries in the Lesser Antilles to develop information tools, including ecosystem modelling and geographic information systems (GISs), collect standard fisheries data, to improve management of their pelagic resources and fisheries in accordance with the EAF. This project was funded by the Government of Japan, that currently is also funding another project providing extended capacity building for the EAF to selected countries mainly through smaller-scale pilot studies and workshops examining the needs and priorities for EAF, and is also supporting ongoing investigations on ecosystem indicators and modelling approaches and the production of an abridged version of the Technical Guidelines on the EAF, aimed at a more general audience.

Another project is being implemented with core funding from the Government of Norway and in partnership with various Global Environment Facility (GEF)–LME regional projects, to strengthen the knowledge base for implementing EAF in developing countries. With an initial focus in the African region, this project will promote capacity building, standardized data collection and monitoring of marine fisheries and related ecosystems, while supporting policy development and management practices consistent with EAF principles.

Several complementary subregional projects that implicitly address the various biological and socio-economical aspects of EAF in the Mediterranean region are also being implemented with funding from the Governments of Greece, Italy, Spain and the EU and in cooperation with the General Fisheries Commission for the Mediterranean (GFCM).

The EAF is an underlying feature of projects funded by the GEF in the Bay of Bengal, Canary Current ecosystem and the Mediterranean Sea, in which FAO is playing a leading role.

The above projects have allowed the introduction of principles and methodologies for the application of the EA in a number of countries and regions, mainly through workshops at the national and regional levels.

2.3 An ecosystem approach to aquaculture: a way to facilitate adaptation to climate change

Introduction

As aquaculture growth worldwide involves the expansion of cultivated areas, a higher density of aquaculture installations and of farmed individuals, greater use of feed resources produced outside of the immediate area, increased use of freshwater, etc., many negative effects have been identified when the sector grows unregulated or under insufficient regulation and poor management.

On the other hand, aquaculture is increasingly affected by external forcing factors or drivers. These include population growth and development especially including other users of aquatic habitats and coastal ecosystems as well as global trade and climate change. All these forcing factors affect the interactions of aquaculture and the ecosystem at all geographical scales, and with a temporal dimension, adding to uncertainty.

Climate change is foreseen as a major driver for all food production sectors, including aquaculture. The main elements of climate change that could potentially affect aquaculture production – such as sea-level and temperature rise, water stress, changes in rain patterns, extreme climatic events and increasing spread of diseases and transboundary pests – require firm and clear adaptation policies and management measures. However, aquaculture can also offer an important alternative and adaptation opportunity when other sectors are more affected. For example, aquaculture, and particularly cage farming systems (non-consumptive water use) and mariculture, are much less dependent on freshwater compared with land-based food production. This is a relevant issue for countries where freshwater is a limiting factor that will be exacerbated by climate change, as seems to be the case for most countries in the Near East and North Africa. The annex to this paper offers a synthesis of potential threats and benefits or opportunities.

Aquaculture also offers opportunities for the reduction and mitigation of GHG production and sequestration of carbon through good aquaculture production practices, such as use of freshwater effluents for irrigation of rice fields and orchards and replanting of mangrove buffers for coastal protection of ponds bordering the sea and a nutrient sink for marine and brackish water effluents.

FAO has recently been working on the formulation of an EAA framework, following the pathway taken by fisheries (Garcia *et al*., 2003), although a systems perspective has been an implicit consideration in aquaculture (FAO, 2007) because, as a farming process, it must take into consideration in explicit ways the inputs, resource use and outputs, including human resources.

"An Ecosystem Approach to Aquaculture (EAA) is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems" (Soto, Aguilar-Manjarrez and Hishamunda, 2008).

The EAA facilitates the adoption of the Code (FAO, 1995) and also responds to the development principles stated in the formulation of the EAF. It has three main objectives within a hierarchical tree framework:

i. ensuring human well-being;
ii. ensuring ecological well-being;
iii. facilitating the achievement of both, i.e. effective governance of the sector/areas where aquaculture occurs and has potential for development.

Two prime goals of the EAA are: (i) to contribute to a "truly" sustainable aquaculture sector (environmentally, economically, socially) considering external forcing factors such as climate change; and (ii) to change the attitude to and perception of the aquaculture sector by the public (in the broadest possible sense).

Key principles

The EAA can be regarded as "the" strategy to ensure that aquaculture contributes positively to sustainable development and should be guided by three main principles, which are also interlinked:

Principle 1

Aquaculture development and management should take account of the full range of ecosystem functions and services, and should not threaten the sustained delivery of these to society.

Developing aquaculture in the context of ecosystem functions and services is a challenge that involves defining ecosystem boundaries (at least operationally), estimating some assimilative capacity and production carrying capacity, and adapting farming accordingly. This should be done for ecosystem services to be preserved or guaranteed. It is important to consider that carrying capacity could change due to climate change. For example, increased temperatures may enhance eutrophication and thereby diminish the previously estimated carrying capacities.

Principle 2
Aquaculture should improve human well-being and equity for all relevant stakeholders.

This principle seeks to ensure that aquaculture provides equal opportunities for development and that its benefits are properly shared, and that it is not detrimental for any groups of society, especially the poorest. It promotes both food security and safety as key components of well-being.

Principle 3
Aquaculture should be developed in the context of other sectors, policies and goals.

This principle recognizes the interactions between aquaculture and the larger system, in particular, the influence of the surrounding natural and social environment on aquaculture practices and results. This principle also acknowledges the opportunity of coupling aquaculture activities with other producing sectors in order to promote materials and energy recycling and better use of resources in general.

Principle 3 is a call for the development of multisectoral or integrated planning and management systems. This is required to account for policies and goals in other sectors as well as to provide a framework and consistent cross-sectoral standards for the delivery of management and development initiatives to meet Principles 1 and 2. This principle is also very relevant under climate change scenarios as adaptation for aquaculture cannot take place in isolation – a watershed perspective is fundamental.

Planning and implementation process

The steps to implement an EAA are depicted in Figure 2.22. To implement an EAA, there must be an aquaculture policy in place; this consists of a broad vision for the sector, reflecting its directions, priorities and development goals at various levels including provincial, national, regional and international. The process starts with the agreement or acceptance of a high-level policy goal. The agreed policy could state something like: “Aquaculture should promote sustainable development, equity, and resilience of interlinked social-ecological systems”.

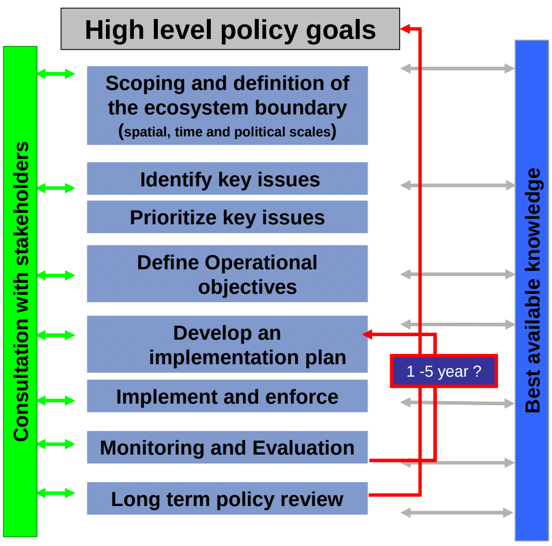

Figure 2.22 The EAA planning and implementation process
Source: Modified from AFPIC, 2009.

Scoping: definition of system boundaries and the relevant stakeholders within
There is a need to define the ecosystem boundaries in space and time when attempting to implement the EAA. The definition of the relevant ecosystem boundaries is a necessary prerequisite exercise including the decision on whether the planning and implementation of the strategy will cover the whole aquaculture sector of a country/region, or (more typically) address an aquaculture system or

aquaculture area in a country/subregion. The definition of the ecosystem boundaries is also needed to identify the relevant stakeholders and to address the different issues (Soto, Aguilar-Manjarrez and Hishamunda, 2008).

Relevant scales

Geographical scales

Farm

The individual farm is easy to locate and identify, and local effects are often easy to assess. However, in cage aquaculture, especially in open ecosystems such as open seas, it may be challenging to establish the boundary of potential effects. Most management practices are developed for this scale and most top-down regulation measures worldwide apply at this scale. Moreover, BMPs are implemented at this level and can be assessed here.

Although it may seem less relevant or meaningful to talk about alteration of ecosystem services at this scale, individual large intensive farms often alter local/site ecosystem functions.

Farmed species escapees and diseases originate and can be prevented/controlled at the farm scale although their effects usually occur at the next spatial scale – the watershed.

Impacts on water and sediment quality and on biodiversity can be dealt with at the farm level, at the "farm group" level, or at a higher level corresponding to some identifiable waterbody, watershed or "agro-ecosystem".

Most top-down regulations and controls, such as environmental impact assessment (EIA), are designed for this scale although in most cases it only applies to large farms (see FAO, 2009). However, they can be adapted to cover the increasing problem from the clustering of small-scale farms as seen in Asia, where the cumulative impact from many small-scale farms can create significant impacts on the environment.

Stakeholders at this scale are usually farm owners, workers, family members, local inhabitants. Many climate-change adaptation measures can be, and are already undertaken by the farmer at the farm level, such as increasing the height of dykes to combat increasing river heights, sea levels and tidal fluctuation.

The watershed/aquaculture zone, geographic region

This is the geographical scale that includes a cluster of farms that share a common waterbody and need coordinated management. This is the scale where most efforts are needed and where the EAA can be most effective in ensuring the sustainable development of the sector.

While the environmental and social impacts of a single farm could be marginal, more attention needs to be paid to ecosystem effects of collectives or clusters of farms and their aggregate, potentially cumulative contribution at the watershed/zone scale, for example the development of eutrophication as a consequence of excessive nutrient outputs.

Escape of alien species or alien genotypes takes place at the farm level. However, the establishment of alien species and genes and relevant impacts on biodiversity occur through whole watersheds. Similarly, disease outbreaks take place first at the farm level but often need control, management and mitigation at the watershed scale. Even more important, adaptation to climate change must in most cases take place at the watershed level, for example to face the spread of a disease or to establish a monitoring programme of water quality (e.g. temperature and salinity) and coastal protection from increasing tidal surge.

Stakeholders and relevant institutions include: clusters of farms/farmers, watershed management bodies, agriculture associations (agriculture, industry and other interacting sectors as well as aquaculture), local communities and local authorities, servicing entities (transport, local dealers, etc.), research and training institutions, etc. The scale at which these entities operate will depend on the nature of the issues.

Regional/global scale
This scale refers to the global industry for certain commodity products (e.g. salmon, shrimp, catfish) and also to global issues such as production, trade of fishmeal and fish oil for feeds, trade of aquaculture products, certification, technological advances, research and education of global relevance etc. Of particular importance is the supply of fishmeal and fish oil in some areas of the world that are feed ingredients for fish and shrimp production in other areas. This means that resources and energy are moving between different regions of the world with unexpected consequences. The sustainability of these resources is particularly important for the long-term sustainability of aquaculture at a global level and the availability of fishmeal can be very sensitive to climate change and, therefore, make global aquaculture very sensitive.

Global issues can be better tackled by organizations such as FAO, World Organization For Animal Health (OIE) or World Trade Organization (WTO) seeking action and coordination between governments. Local and regional issues are typically best addressed at some level corresponding to an identifiable aquatic system or agro-ecosystem, although a compromise may have to be struck depending on the nature and scale of existing or potential management systems and associated institutions.

Regional fishery bodies (e.g. the GFCM and RECOFI) are very relevant at both watershed aquaculture zone and at regional and global scales.

Temporal scales
Because aquaculture is affected by external forcing factors or drivers such as climate change, it is necessary to apply a precautionary approach owing to unknown ecosystem threshold or resilience, including the human components. Therefore, time scales are relevant in strategy and planning.

Identification and prioritization of issues
The identification of issues should be constrained to the system boundary and also to the ability of addressing the issue. The different issues related to aquaculture activities have been discussed at length in numerous publications (FAO, 1997, 2006, 2007, 2009; Soto, Aguilar-Manjarrez and Hishamunda, 2008). However, it is, as always, relevant to define a clear methodology for the identification and clarification of these together with relevant stakeholders.

For the purpose of the present paper, we focus more on issues/impacts of aquaculture on the ecosystem that are exacerbated by climate change and issues/impacts of climate change on aquaculture.

Issues related to aquaculture effects on the ecosystem
Because aquaculture as a production process requires land, water and specific inputs to produce expected outputs (together with unwanted outputs), issues affecting ecological and social well-being can be associated with the main parts of the process, as shown in Figure 2.23. Usually, direct impacts are of greater concern; nevertheless, indirect impacts can also be relevant. For example, looking under Inputs and into the “Feeds” box in Figure 2.23, the use of trash fish and/or small pelagics to feed tuna could have a negative impact on the small pelagic stocks (Figure 2.24). However, many small-scale artisanal fishers live on these fisheries and benefit from the price paid for tuna feed, and so there is a positive livelihood effect when they do not have other choices (Figure 2.25). Other indirect negative effects could be on wild predator species that live on these pelagic species (e.g. in a nutrient-deficient ecosystem such as the Mediterranean Sea).

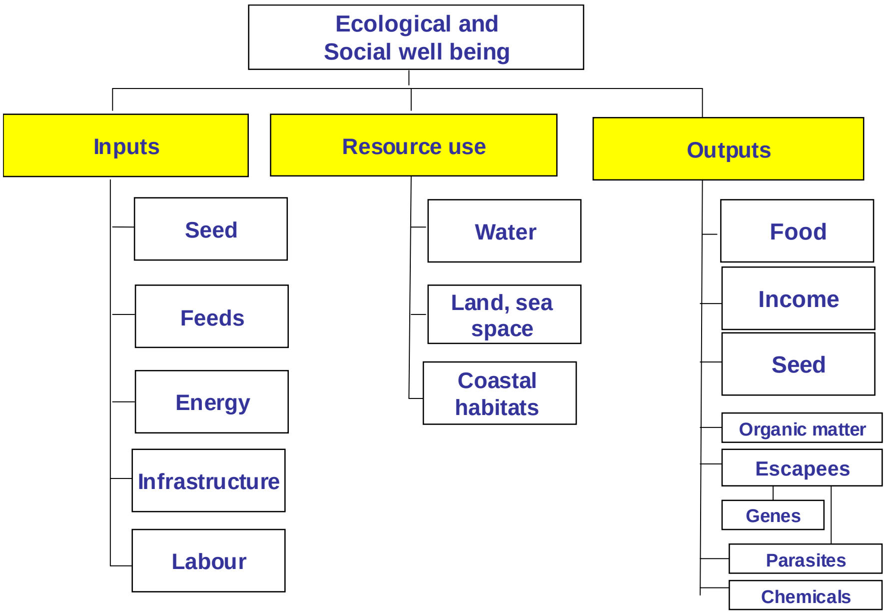

Figure 2.23 Main issues relating to aquaculture impacts on the ecosystem

Types of issues
It is also important to distinguish clearly different types of issues when examining the boxes in Figure 2.22 as there may be ecological, social and "ability to achieve" issues. The latter are related to governance and institutional factors, and most often these are the root cause of the ecological and social issues. Other external forcing factors such as climate change should also be considered under "ability to achieve", also catastrophic events, international market crashes, etc. In the example mentioned above, the feeding of small pelagics to tuna farms encompasses ecological, social and "ability to achieve" issues as already described.

Indeed, a relevant external forcing factor on the aquaculture sector is climate change (De Silva and Soto, 2009), although time scales are not clear. Using the same example described above, climate change could have a strong impact on small pelagic stocks, thereby exacerbating the human harvest effect, to feed tuna in the farms. Therefore, the EAA must consider such events within agreed time scales, particularly at the watershed/waterbody scale (e.g. the Red Sea, the Mediterranean Sea).

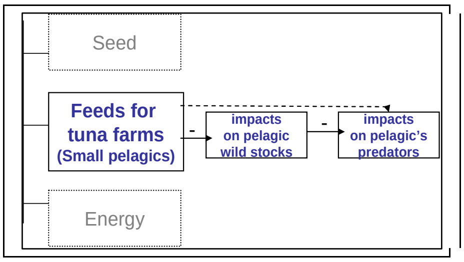

Figure 2.24 Ecological issues relating to aquaculture feed

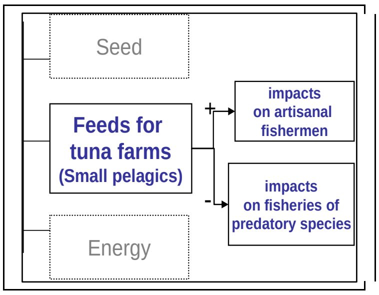

Figure 2.25 Social issues relating to aquaculture feed

Identification process requiring background documentation and knowledge
Proper identification of issues requires: (i) involving the relevant stakeholders for the selected system (within the defined boundaries in the scoping process); (ii) adequate background information available to all these relevant stakeholders; and (iii) a facilitation process including a "neutral facilitator".

Issues related to inputs
Aquaculture has a number of inputs as part of the farming process (Figure 2.26). Climatic changes negatively affecting these inputs will have an effect on aquaculture productivity and on the communities dependent on aquaculture as a livelihood. Such is the case of freshwater.

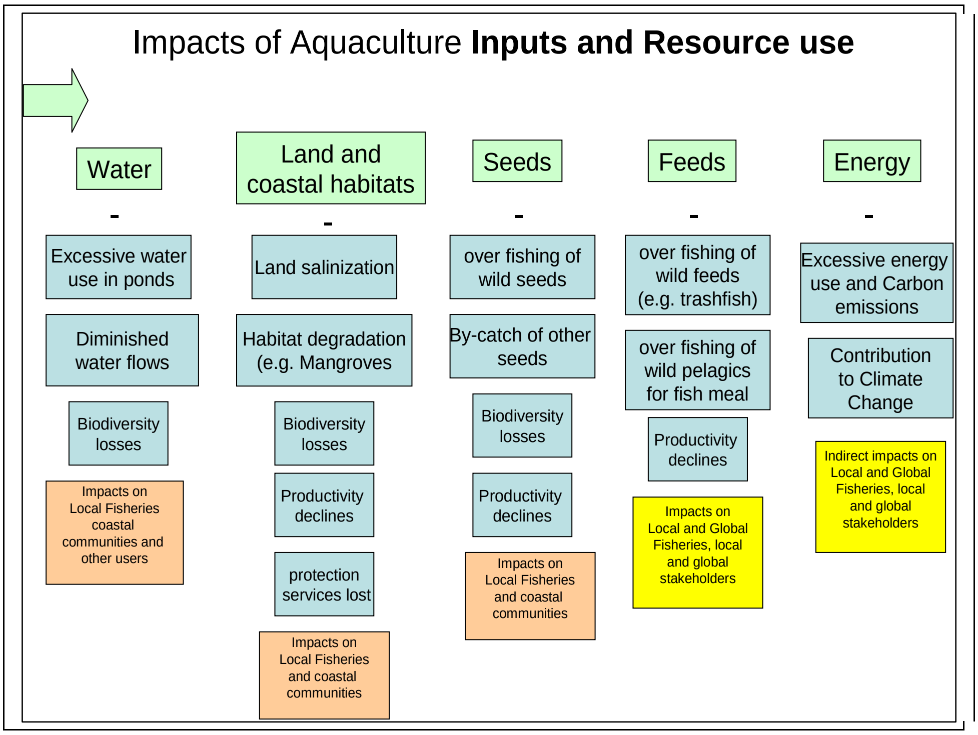

Figure 2.26 Impacts of aquaculture inputs and resource use

Freshwater
The water requirement for various aqua-ecosystems ranges from 0.1 to 0.2 m^3/kg of fish production for recycling systems through 2.0–6.0 m^3/kg for intensive fish ponds up to 500–900 kg/m^3 for flow-through systems, although raceways associated with springs or streams only "borrow" the water as the water flows through the culture facility so quickly. Pond aquaculture is a water-intensive practice because large amounts of water are needed to fill the pond and maintain the water level throughout grow-out because of losses from evaporation and seepage.

Pumping of water from boreholes is increasingly common for both agriculture and aquaculture, and consequent lowering of the water table has become a significant issue. Pumping of freshwater from boreholes near the sea may in addition cause saline intrusion underground. The deliberate introduction of seawater to inland areas also occurs in some countries where shrimp culture has been extended inland. Climate change is affecting freshwater availability, putting more pressure on the resource.

Seeds
Capture-based aquaculture is reliant on the capture of fry, juveniles or broodstock. Examples include the collection of wild milkfish fry and elvers (eel fry). The collection of juvenile tuna for fattening, or the collection of wild broodstocks for *Penaeus monodon* culture, if undertaken on a wide-scale basis, can affect the natural populations.

Climate change is predicted to have impacts on ocean productivity, fish migration and recruitment. This together with continued habitat deterioration, overfishing, etc. will affect the availability of seeds from the wild. Therefore, increased efforts should be made to increase the production of seeds in hatcheries. Other adaptation advantages could include research and genetic selection of seeds better adapted to new environmental conditions.

Feeds
Most modern forms of aquaculture are dependent upon the input of compound feed, with fishmeal or fish oil as a significant ingredient. There are concerns for the unknown biogeochemical consequences of global net transport for elements such as nitrogen, phosphorus and carbon, mostly from the southern hemisphere to the northern hemisphere, partly driven by aquaculture. Other relevant concerns are those related to the global environmental costs or “footprints” of aquaculture in terms of energy, water usage, and carbon production.

The use of fishmeal and fish oil makes the largest CO_2 footprint in aquaculture owing to the energy requirements of pelagic fisheries. On the other hand, the culture of fish higher in a trophic food web, that is carnivorous fish, require a higher proportion of fishmeal while herbivorous fish, such as carps and tilapia, have greater yields with lower or no fishmeal inputs.

The culture of filter feeder species (e.g. mussels and clams) and extractive species (seaweeds) not only offer food and development opportunities but they also have a very low or zero CO_2 footprint, provide other services such as extraction of excess nutrients in coastal zones, and absorb carbon (in the case of seaweeds). Such aquaculture forms could eventually gain access to “carbon credits” such as is the case with some land forestry and certain forms of agriculture – possibilities under current discussions under climate change mitigation.

Issues related to outputs

Food supply
Food is the most relevant socio-economic output of the aquaculture process. Aquaculture contributes towards the nutritional needs of a wide cross-section of human populations. Fish is the only affordable source of animal protein available to the poor in some parts of the world. Small-scale aquaculture generates food for the producer’s household and in the immediate community, and thus contributes to social resilience. Aquaculture is an increasingly important source of high-quality animal protein for direct human consumption and, where production is geared towards national urban and international markets, local people earn incomes sufficient to purchase foods produced elsewhere.

Food production through aquaculture can offer adaptation options under some climate change stresses such as freshwater scarcity. For example; cage farming in reservoirs and lakes offers an opportunity to produce protein with very reduced freshwater use (only through feeds).On the other hand, mariculture can offer solutions for coastal agriculture communities affected by droughts or by sea-level rise and salinization of coastal areas.

Seeds and juveniles for stock enhancement
The aquaculture production of seeds and larvae for the establishment of new/additional fish resource for fisheries and livelihoods is an important positive output of the process. Hatchery-produced larvae can also contribute to the conservation and improvement of endangered species. Restocking to enhance fisheries or to recover endangered stocks can provide important opportunities also under climate change threats

Excessive nutrients and chemicals
Water effluent from aquaculture that uses feed has increased nutrient levels. This can affect water quality and the downstream use of that water.

Because of the production process, there are unwanted outputs such as excess nutrients, escapees and chemicals. This can lead to some loss of biodiversity or affect ecosystem[8] services. The resulting loss of biodiversity is a sacrifice that most developing economies are quite willing to make so long as this does not undermine the delivery of the valued services themselves in the medium and long terms. However, there is increasing appreciation that changes to current practices are required as some of these services are being compromised (instability in production; pollution; flooding; erosion; dwindling or poor quality water supplies).

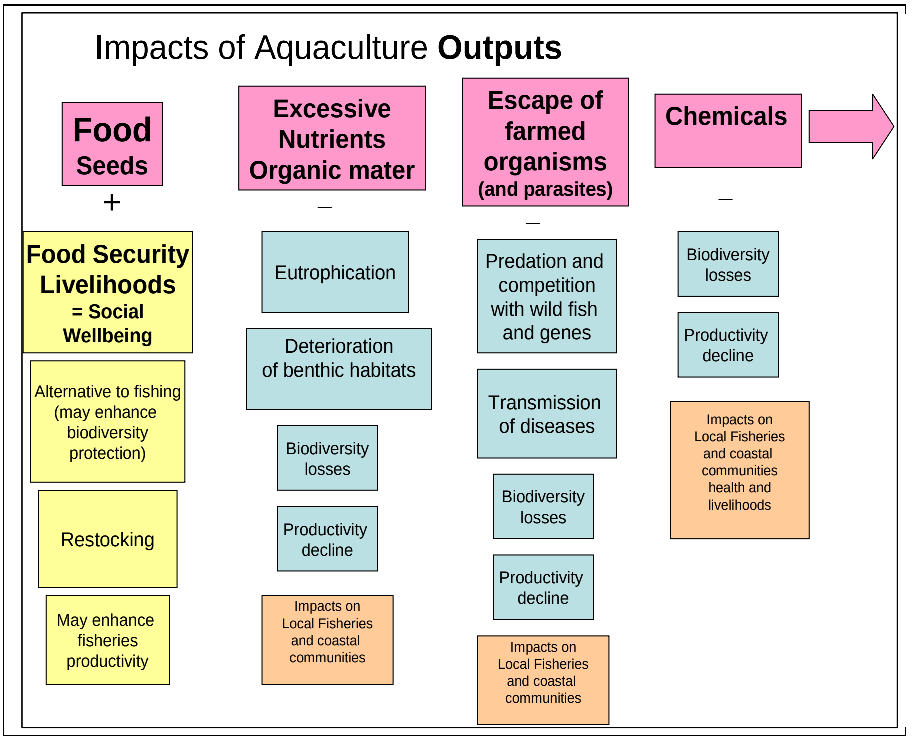

Figure 2.27 Impacts of aquaculture outputs

Biodiversity presents a dilemma. Extensive systems promote relatively higher biodiversity but require a large area to generate a tonne of fish. In contrast, more intensive systems are characterized by low biodiversity but require little space, leaving more aside as natural habitat and "green infrastructure".

The local (farm) impacts of excess nutrients on sediments and, therefore, on biodiversity and ecosystem services from fed aquaculture or accumulation of particulate organic matter from filter feeders are well known and are being addressed in many ways. Often, however, the considerations of ecosystem carrying capacity to support nutrient inputs are not taken into consideration.

Prioritization of issues

A large number of issues related to aquaculture impacts or impacts of external drivers on the sector can be identified but their importance varies greatly. Prioritization of issues will also help to define operational objectives and to define the plan within the strategy (Figure 2.28). Both the identification of issues and prioritization must be fully participatory – including relevant stakeholders. In this way, decisions and further actions have ownership and can be better implemented.

[8] An ecosystem is defined by the Convention on Biological Diversity (CBD) as "a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit" (CBD, 2004).

To determine the priority of issues and therefore the appropriate level of management response, the process uses risk analysis methods. A number of risk analysis tools can be used to assist this process. It is important to define the concept of hazard in aquaculture. This would be a physical agent or event having the potential to cause harm or to impair the ability to achieve our high-level objectives. These often include: a biological pathogen (pathogen risk); an escaped aquatic farmed organism (genetic risk, ecological risk, invasive alien species risk); a chemical, heavy metal or biological contaminant (food safety risk); excess organic matter (eutrophication risk); and the loss of a captive market (out of business risk, unemployment risk, etc.). Risks associated with increased water temperature, salinity and increased eutrophication potential can be climate-change-related threats. All risk assessment methods work by assessing the "risk" of not meeting the objectives (which are affected by the values/outcomes wanted – see above). A risk analysis typically seeks answers to four questions:

i. What can go wrong?
ii. How likely is it to go wrong?
iii. What would be the consequences of its going wrong?
iv. What can be done to reduce either the likelihood or the consequences of its going wrong?

Whichever risk assessment method is used, it must include appropriately detailed justifications for why the levels of risk were chosen[9]. This allows other parties who were not part of the process to be able to see the logic and assumptions behind the decisions that were made. It also helps when reviewing the issue sometime in the future – unless you know why you choose the levels, it will be hard to know if anything has changed that may require a shift in the risk levels and, therefore, management actions. This also assists in understanding the knowledge "gap" analyses/uncertainties.

Following steps in implementing the strategy

Following steps in the implementation plan of the EAA include: the establishment/definition of overall objectives and operational objectives; and the establishment of minimum requirements. These should include: (i) assess existing legal policy (high level) and institutional frameworks; (ii) create/enhance enabling legal frameworks; (iii) strengthen, modify or create new institutional arrangements; (iv) create human capacity; and (v) develop management measures with an ecosystems perspective. The operational objectives and the plan should provide a way to address the issues described in Figures 2.23–2.27.

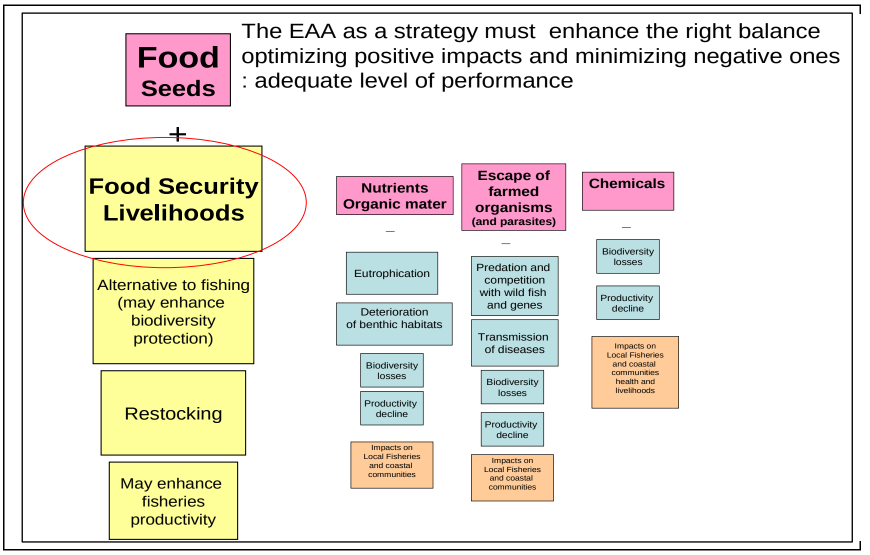

Figure 2.28 The EAA as a strategy

[9] A detailed methodology and case studies can be found in Bondad-Reantaso, Arthur and Subasinghe (2008).

Management measures that are relevant for facing climate change

Most relevant management measures at the farm scale include: (i) proper site selection and considerations of carrying capacity aspects and biosecurity in general; (ii) adoption of BMPs by individual farmers and clusters of farmers (De Silva and Soto, 2009). Practices including proper feeding and optimization of feed conversion factors can improve both climate change adaptation and mitigation aspects. Health management of farmed species and prevention of escapees are also relevant measures. Water warming and related low oxygen, eutrophication enhancement, etc. can be avoided or minimized in deeper sites with better circulation. However, there are always trade-offs with exposure to more extreme conditions. The likelihood of the spread of disease can be minimized by increasing the minimum distance between farms and by implementing tight biosecurity programmes for aquaculture clusters or zones.

However, the EAA at the watershed scale is most relevant. Here, a proper aquaculture zoning mechanism, biosecurity frameworks, risk analysis and strategic environmental assessments (FAO, 2009) that take into account the added effects of many farms are very relevant to better face potential threats such as new diseases, invasive species, and eutrophication-related problems that can be exacerbated by climate change (e.g. increased water temperature and salinity).

According to De Silva and Soto (2009), implementing proper risk communication is also very important. For aquaculture, some of the most important prevention systems must rely on critical and effective monitoring of waterbodies and aquatic organisms. A very important adaptation measure at the local level and at the waterbody/watershed scale is the implementation of effective integrated monitoring systems. Such monitoring systems should provide adequate information on physical and chemical conditions of aquatic environments, early detection of diseases and presence of pest species, including harmful algal blooms.

The integration of aquaculture with other sectors can be very important at the watershed scale. Aquaculture development affects and is affected by other human activities such as fisheries, agriculture, irrigation and industry as well as increasing urbanization, so their relative contribution to environmental degradation needs to be assessed and controlled. 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 salinization of deltaic areas leading to loss of agricultural land.

National climate change adaptation and food security policies and programmes would need to be fully integrated with the 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 aquaculture (e.g. irrigation infrastructure, dams, fertilizer use runoff), and will require carefully considered trade-offs or compromises.

Integrated aquaculture can offer relevant benefits including bioremediation, such as in the case of integrated multitrophic aquaculture (IMTA). Reducing risks is another advantage and profitable aspect of farming multiple species – a diversified product portfolio will increase the resilience of the operation, for example when facing changing prices for one of the farmed species or the accidental catastrophic destruction of a crop for example due to climate change[10]. However, some of the normative elements that are necessary to enhance this practice are not yet in place, e.g. appropriate legal frameworks.

[10] A recent review (Soto, 2009) provides a global perspective on the potential for integrated mariculture in coastal zones, including the Mediterranean Sea, where some of these advantages are well explored.

Aquaculture diversification and, especially, exploring new opportunities in mariculture potentially offer new adaptation options. By moving away from freshwater, both the impacts on this resource and the competition with other sectors for its use are strongly reduced. Further aquaculture movement off the coast and offshore can reduce impacts on coastal zone habitats and competition with other users (e.g. tourism), but greater exposure to rougher seas is part of the trade-off. Economic and social costs and benefits must be considered as well. A last but not least important aspect is that the implementation of the EAA must necessarily enhance and promote the culture of herbivorous/omnivorous species, especially filter feeders and extractive species. By doing this, there is a minimization of inputs external to the system.

Conclusions

The EAA emphasizes the need to integrate aquaculture with other sectors (e.g. fisheries, agriculture, urban development) that share and affect common resources (land, water, feeds, etc.) also focusing on different spatial scales: (i) the farm; (ii) the aquaculture zone, waterbody or watershed where the activity takes place; and (iii) the global scale (Soto, Aguilar-Manjarrez and Hishamunda, 2008). Perhaps the implementation of the EAA at the waterbody scale is one of the most relevant adaptations to climate change. The geographical remit of aquaculture development authorities (i.e. administrative boundaries) often does not include watershed boundaries and this is a particular challenge because climate change prevention and adaptation measures need watershed management, e.g. protecting coastal zones from landslides, siltation, discharges, or even simply providing enough water for aquaculture. On the other hand, aquaculture can provide adaptation for coastal agricultural communities that may face salinization effects because of rising sea levels.

In coastal regions, mariculture can provide an opportunity for producing animal protein when freshwater becomes scarce. Such a watershed perspective needs policy changes and integration between different sectors (e.g. agriculture–aquaculture), aside from capacity building and infrastructure requirements. Because climate change does not recognize political boundaries, adaptation policies and planning within international watersheds can be a major challenge. However, the common threat of climate change impacts can provide the opportunity for such transboundary management. For the aquaculture sector, the watershed-scale approach is also needed for an organized, cluster-type adaptation to negotiate collective insurance, to implement appropriate biosecurity measures, etc.

An EAA is being increasingly considered as a suitable strategy to ensure sustainability, including adequate planning required to take into account climate-change impacts.

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Annex – Climate change related impacts on aquaculture and potential risks and opportunities/benefits

Climatic change element	Impacts on aquaculture or related function	Benefits or risks
Warming: - Long-term gradual warming - Short-term exceptional warm periods	Decreased productivity	Temperature rise above optimal range of tolerance of farmed species Higher stress
	Increased productivity	Increase in growth; improved feed conversion ratio Shorter production cycle
	Changes in wild fisheries	Availability change in wild broodstock, fry collection
	Increase in disease incidence	Increased virulence of dormant pathogens and expansion of new diseases
Sea-level rise	Intrusion of saltwater	Reduction in freshwater culture area Relocation of freshwater culture upstream Increased area for brackish-water culture
	Loss of agricultural land	Provide alternative livelihoods through aquaculture
	Coastal erosion	Coastal pond damage
Ocean circulation changes	Changes in coastal upwelling	Reduced catches from coastal fisheries Limitations on fishmeal and fish-oil supplies/price
	Changes in ocean circulation	Seedstock disruptions, less availability of trash fish
Acidification – ocean and freshwater	Impact on calcareous shell formation/deposition in marine waters	Problems with mollusc production Changes in plankton populations
	Increased incidence and level of acid rain	Problems with mollusc production Changes in plankton populations
Changes in precipitation pattern	Increased rainfall – flooding	Increased incidence of flooding Loss of stock, damage to farm facilities Changes in water quality
	Decreased rainfall – drought	Limitations for freshwater abstraction
	Changes in rainfall timing – early or late rains	Unpredictable production seasons Difficulty in pond preparation (drying)
	Changes in precipitation pattern	Change in water-retention period (inland systems reduced, coastal lagoons increased)
	Change in monsoon patterns	Unpredictable freshwater supply
Extreme weather events	Increased typhoon strength and change in location	Destruction of facilities; loss of stock; loss of business; mass escape with potential to impact on biodiversity
	Increased storm events	Damage to cages, pens and longlines Damage to coastal ponds Disruption of production
	Increased storm surge	Coastal pond damage, increased saline intrusion

2.4 Climate change and fisheries

Overview of ecological and biological impact pathways

Under IPCC scenarios, water and air temperatures in mid- to high latitudes are expected to rise, and sea-level rise combined with increased frequency and intensity of extreme events will affect coastal zones. In a recent review, Brierley and Kingsford (2009) identified some of the direct consequences of global warming on marine environments such as increasing global temperature, perturbed regional weather patterns, rising sea levels, acidifying oceans, changed nutrient loads and altered ocean circulation. These changes will unfold at different time scales but are already occurring at an alarming rate with sea levels rising by more than 15 cm in the last century and a global mean temperature rise of 0.75 ºC above pre-industrial values (Table 2.3). While marine ecosystems have experienced warm conditions in the past they have never experienced acidification conditions as high as present (Barange and Perry, 2009). Increase in atmospheric CO_2 results in more CO_2 in the ocean, increasing ocean acidity, thus reducing pH in the last 200 years (Table 2.3). These and other physical changes will affect ecological and biological processes that are critical to aquaculture productions systems.

Drivers of changes in aquaculture production systems related to climate change can be identified as: changes in sea surface temperature, changes in other oceanographic variables (wind velocity, wave action, etc.), sea-level rise, increase in extreme events and water stress. These changes will in turn create physiological (growth, development, reproduction, disease), ecological (organic and inorganic cycles, predation, ecosystem services) and operational (siting, sea cage technology etc.) changes (Table 2.4).

Water and air temperatures in mid- to high latitudes are expected to rise, with a consequent lengthening of the growing season for cultured fish and shellfish. These changes could have beneficial impacts with respect to growth rate and feed conversion efficiency. Production of shrimp farms usually increases along the Pacific coast of South America during El Niño years. The maturation, spawning, and recruitment of post-larvae and the migrations of the immature juveniles are strongly correlated with seasonal to interannual variability of oceanic temperatures off the Ecuadorian coast (Cornejo-Grunauer *et al.*, 1997). Shrimp thrive in the warm El Niño waters and grow rapidly in the brackish-water environment created by the heavy rains, which also flush out the ponds and estuaries. Wild shrimp reproduce in great numbers during El Niño periods, supplying farmers with endless quantities of the highly-prized, wild post-larvae, while during La Niña (colder waters) the opposite happens (Cornejo-Grunauer, 1998). Shrimp hatcheries have difficulty competing with the abundant wild seedstock and most temporarily close their doors (Rosenberry, 2004).

However, tropical species are often already near their lethal thermal limits, and a slight temperature change might have significant effect on their physiology. In the case of bivalves, it has been shown that tropical species live closer to their maximum habitat temperature than the temperate species (Comptona *et al.*, 2007). Tropical bivalves are thus closer to their upper lethal thermal limits than are temperate species, suggesting that temperate species are better adapted to temperature variation. It is important to note that temperature responses are species-specific, and while some species will be adversely affected, others who are better adapted to high temperature and possess a wide thermal tolerance zone, such as the catfish *Horabagrus brachysoma*, could be introduced in tropical freshwaters (Dalvia *et al*., 2009). Temperature change will thus have a direct impact on the species suitable for farming in any specified area. It will also indirectly influence other factors such as oxygen, pests, diseases and the occurrence of toxic algal blooms and paralytic shellfish toxins (2WE Associates Consulting Ltd, 2000; Moore *et al*., 2009). In Tasmania (Australia), warmer currents linked to climate variability and change are said to affect salmon in fish farms by slowing growth and increasing the presence of algae blooms and gill amoeba – a parasite on the fish that can lead to increased mortality (Paine, 2003).

Sea level rise will gradually affect marine and brackish aquaculture with saltwater intrusion, requiring the farming of high-salinity tolerant species. Increasing extremes of weather patterns and storms will be another hazard to coastal industries. Storm surges, waves, and coastal erosion are likely to have a larger effect than the rise in mean high water level (2WE Associates Consulting Ltd, 2000). Fluctuations of water level in freshwater lakes and deltas caused by changes in precipitation will also affect inland aquaculture, resulting in additional waters stress and salinity changes in certain cases. In the United States of America, droughts, which are linked to higher average temperatures, have in the past caused slower growth of catfish and increase the possibility of outbreak of diseases. In order to harvest the catfish at marketable sizes, producers had to care longer for them, which significantly increases production costs (*AgJournal*, 1999). In the eastern Hemisphere, El Niño, with its decrease in rainfall, usually has a negative effect on aquaculture production. In the Philippines, tilapia production from freshwater ponds dropped by 2.7 percent, probably owing to the prolonged drought caused by the 1997–98 El Niño. During the same period, seaweed production dropped slightly (by 0.7 percent) apparently also due to the El Niño (Yap, 1999).

Acidification can be expected to narrow the thermal tolerance for fish. Episodic hypoxaemia will manifest as reduced growth, impaired feed conversion efficiency and increased susceptibility to infectious agents (Forsythe, 2009). Impacts on calcification resulting in shell malformation will also occur. In a recent study, the exposure of edible mussels (*Mytilus edulis*) and Pacific oysters (*Crassostrea gigas*) – two important aquaculture species – to more acidic conditions for a few hours resulted in immediate diminishing of shell calcification. The linear decrease in calcification rates with increasing CO_2 suggest that, under IPCC scenarios, marine organisms might be negatively affected by lower pH (Gazeau *et al*., 2007).

Table 2.3 Time scale of changes and approximate values of changes pertinent to marine environments

	Time scale						
	Geological	Oscillatory change		Secular change			
	(Cenozoic -)	Orbital/ Milankovitch	Recent Decadal	0 to industrial revolution, 1850	Post-industrial to present	Present to 2100	2100–4000
No. years	10^6 to 10^7	10^4 to 10^5	10s	c. 2k	c. 150	c. 100	c. 2k
Temp. at end, °C cf. 1850	'Icehouse' to 'greenhouse'	Glacial-interglacial; -8 to +5 [149]	+/- 2 (detrended) [40]	Stable between -1.2 to +0.4 [32]	+0.75 [6]	+2.5 to +5.5 [136]	+10 [150]
$CO_{2[atm]}$ ppm	150 to 3500 [36]	172 to 300 [149]	+/- 1 (detrended) [40]	Stable between ~274 and 282 [149]	385 (in 2008) [42]	450 to 1000 [136]	1700 to >2000 [150]
pH	7.3 to 8.3 [36]	Varies by 0.16 [13]	Stable	Stable around 8.2 (+/- 0.3) [13]	-0.1 [13]	-0.3 to -0.5 [13]	-0.77 [57]
Sea ice coverage, %	0 to mid latitude [31]	High latitude to mid latitude	Regionally variable [118,151]	Stable, c. 7% Earth's surface [152, 153]	Antarctic stable to -25% Arctic -20% [112, 152]	-40% cf. 1999 [111]	-90% [150]
Sea level, m		-130 to 0 [154]	Stable	Stable	+0.2 [12]	+0.5 to +1.4 [12]	+100
AMO circulation	Direction reversals	-40% to +40% [37]	Variable [155]	Variable	Variable 18.7 +/- 5.6 Sv [29]	-50% [155]	3 Sv to collapse [100,150]
Suboxic volume	Highly variable	Variable	Stable	Stable	Expanding [56]	+50% [66]	+300% [150]
Species events	Range changes & extinctions	Range changes	Regime shifts	Stable	Range changes	Range changes & extinctions [156]	Mass extinctions

Source: Based on Brierley and Kingsford (2009) and references therein.

Table 2.4 Possible climate-change impacts on aquaculture

Drivers of change	Physiological impacts	Ecological impacts	Operational impacts
Sea surface temperature changes	Increase in harmful algal blooms that release toxins in the water and produce fish kills Spread of pathogens and disease Decreased dissolved oxygen Increased incidents of disease and parasites Enhanced growing seasons Lower natural winter mortality Enhanced growth rates and feed conversions (metabolic rate) Enhanced primary productivity (photosynthetic activity) to benefit shellfish production of filter-feeders	Competition, parasitism and predation from exotic and invasive species Altered local ecosystems – competitors and predators Decrease in sea-ice cover	Increased infrastructure and operation costs Increased infestation of fouling organisms, pests, nuisance species and/or predators Moratorium on products due to bans Expanded geographic distribution and range of aquatic species for culture
Change in other oceanographic variables (variations in wind velocity, currents and wave action)	Decrease flushing rate, which can affect food availability of shellfish	Change in water exchanges and waste dispersal	Accumulation of waste under pens Increased operational costs
Sea-level rise	Changes in salinity affecting growth especially brackish-water fish	Reduced ecological areas available for aquaculture	Damage to infrastructure Changes in aquaculture zoning Competition for space with ecosystems providing coastal defence services (i.e. mangroves) Increased insurance costs
Acidification	Calcification: affecting growth and development of shellfish. Affecting growth and exoskeleton of fish Change in productivity due to phytoplankton species shifts	Coral skeleton growth hindered	Changes in species
Extreme events (floods, droughts hurricanes, storms)	Changes in salinity affecting growth especially brackish-water fish		Higher operational costs, need to design cages moorings, jetties etc. that can withstand events Negative effect on pond walls & defences Increased insurance costs
Water stress (increasing evaporation rates and decreasing rainfall)	Decreased water quality leading to increased diseases	Reduced lake level Altered and reduced freshwater supplies	Costs of maintaining lake level artificially Conflict with other water users

Note: This table is not intended to be comprehensive but to give examples of potential impacts.
Sources: Modified from 2WE Associates Consulting Ltd (2000), Johannes (2004) and Milewski (2002).

The impacts of global environmental change on other production systems are also likely to affect aquaculture production systems. The fluctuation in supply of fish oil and fishmeal and its possible impact on aquaculture production is illustrative of such linkages. More than half of global aquaculture production was freshwater finfish in 2006, and finfish culture production in developed countries is mostly carnivorous species (FAO, 2007). The price and availability of fishmeal and fish oil inputs is a non-trivial issue to fish farmers practising intensive culture of carnivorous species; feed costs represent up to 60 percent of their total operating cost (Stikney, 1994). Fluctuation of fishmeal production owing to climate variability can thus have significant effects on the livelihoods of fish farmers. The case of the Peruvian anchoveta is a stark example of the possible impact of climate change on fish farmers' livelihoods. Since 1976, the combined share of Peru and Chile in world fishmeal production has averaged 34 percent (Delgado *et al*., 2003). In 1997–98, an El Niño event decreased the harvest of Peruvian anchoveta, leading to soaring prices of fishmeal.

Changes in capture fisheries can also have an impact on the aquaculture sector through changes in bycatch. In Asia, bycatch or "trash fish" is often transformed into fishmeal for the local and regional aquaculture markets. For example, in China, as much as 5 000 000 tonnes of fish were being used for fishmeal, livestock and aquaculture feed by 2001 (Grainger *et al*., 2005). In Viet Nam, local fishmeal ("fish powder" produced in a artisanal way) is mainly used to feed livestock and some freshwater fish for grow-out feed, as it is generally of poor quality; only 10 percent of the fishmeal is estimated to be locally produced (Edwards *et al*., 2004). However, future demand for fishmeal is expected to increase dramatically as aquaculture production increases and some species, such as catfish, are increasingly fed pelleted diets containing fishmeal. Overexploitation combined with changes in fish biomass induced by climate change could have repercussions for the aquaculture sector, especially for farmers who rely on low-cost fishmeal inputs.

Indirect impacts arising from adaptive strategies pursued by different sectors may also be significant and compound the effects of direct climate impacts on aquaculture production and dependent livelihoods (Badjeck *et al*., 2009a). These potential interactions make impact predictions difficult to make and more uncertain. For example, increased sea-level rise might prompt the development of coastal defence systems, which will limit the availability and suitability of culture sites. Adaptive strategies by the agriculture sector that focus upon the construction of more flood control, drainage and irrigation schemes might influence water quantity and characteristics (salinity, pH, etc.) of aquaculture systems, prompting changes in species.

Finally, the livelihoods perspective can be used to understand impacts of climate variability and change on livelihoods capitals of households and communities dependent on aquaculture. The next section presents some of the impacts of climate variability and change on the physical, financial, human and social capitals (natural capital has already been covered in this section).

Impacts on aquaculture-based livelihoods

Damage to physical capital and reduced financial capital

Any increases in the intensity and frequency of extreme climatic events, such as storms, floods and droughts will have a negative impact on aquaculture production and may result in significant infrastructure damage – mainly related to decreased farming capacity (loss of infrastructure) or decreased access to markets (damaged roads). This often translates into economic losses that small fish farmers are unable to cope with. In Indian River Lagoon, Florida (the United States of America), the Florida Department of Agriculture estimated that Hurricane Frances and Hurricane Charley (2004) caused USD8.7 million in crop losses for clam and oyster farmers, with USD7.2 million of that caused by Hurricane Frances (Bierschenk, 2004). The State of Florida's shellfish industry is primarily comprised of clam farmers. This number does not include infrastructure losses, such as buildings, docks, vessels, and nursery and hatchery facilities. In Collier County, the clam industry lost 100 percent of its food clams, according to state agricultural officials.

In Bangladesh, the 2004 floods caused damage to the aquaculture sector. Fish farms overflowed and in the Chandpur District most of the 13 000 fish farms lost part of their stock, which translated into economic losses of about USD3.5 million (Growfish, 2004a). In the village of Sobulia in Fulpur, freshwater shrimp farms on some 30 acres (about 12 ha) of land were washed away by floodwaters (Hague, 2004). The Bangladesh Small Fishermen Association estimated that fires and growing niches of 80 percent of waterbodies in 45 flood-hit districts were washed away causing significant losses to cultivators. Most fish farmers did not have the financial resources to repay some of the loans they had contracted to enter the fish-farming business and they made an appeal to the government to supply interest-free loans and supply of fish fry free of cost from government hatcheries (Growfish, 2004b).

In Latin America, although Ecuador's production of farmed shrimp increases during El Niño, strong El Niños, like the ones in 1981–82 and 1997–98, result in a net loss to the industry (Rosenberry, 2004). Roads and bridges were washed away, limiting access to processing plants, and low-lying ponds were flooded (Cornejo-Grunauer, 1998; Rosenberry, 2004). In Nicaragua, small, government-backed cooperatives occupy the backwater areas, where the flooding was the heaviest during the El Niño. An estimated USD2 million worth of shrimp escaped; overall, Nicaragua lost 25–30 percent of its 1998 crop, and the industry suffered an USD8 million loss (Rosenberry, 1999). In Honduras, about 10 percent of the total farm infrastructure was damaged by storms, primarily as erosion damage to pond dykes and flooding of farm buildings (offices, workshops, and feed/fertilizer storage buildings). In addition, a lot of equipment, vehicles, machinery and pumps were damaged or destroyed (Rosenberry, 1999).

Reduced human capital and impacts on social capital

Climate variability and change may, through increased extreme events, have an impact on employment in the aquaculture sector and result in resource-use conflicts. The 1997–98 El Niño Southern Oscillation event significantly affected employment in the aquaculture sector, with the collapse of shrimp hatcheries (approximately 300) that affected about 6 000 people (Cornejo-Grunauer, 1998).

In Thailand and Taiwan Province of China, intensive shrimp farming has led to pumping large volumes of underground water to achieve brackish-water salinity, leading to a lowering of groundwater levels and salinization of adjacent land and waterways (Braaten and Flaherty, 2001; Dierberg and Kiattisimkul, 1996; Primavera, 1998). Salinization reduces water supplies not only for agriculture but also for drinking and other domestic needs (Primavera, 1998). Under increased climate-change scenarios, which increase the frequency of droughts and floods, availability of freshwater might be a source of conflict between the aquaculture sector and other sectors (e.g. rice agriculture), or at the least become an impediment factor for the full development of aquaculture. Aquaculture can cause habitat modification by affecting such ecosystem services as coastal protection and flood control by removing mangroves (Naylor *et al*., 2000). Conversion to shrimp ponds has been the main cause of mangrove loss in the last few decades in Bangladesh and Sri Lanka, while in Viet Nam a total of 120 000 ha of mangroves was cleared for shrimp farming between 1983 and 1987 (Primavera, 1998). In the context of increased extreme events driven by climate change, there is an incentive to reclaim mangrove areas, which in the long run could lead to conflicts between aquaculture producers and other users of the coastal zone.

Climate change in the context of multiple pathways and multiple drivers

As described above, climate change will affect the aquaculture sector through indirect and direct pathways. These are illustrated in Figure 2.29, with Table 2.5 providing a specific example for Viet Nam. It is important to note the additive and multiplicative impacts of climate change on other non-climate stressors. Indeed, indirect climate effects mediated through socio-economic pathways may interact with, amplify or even overwhelm biophysical impacts on fish ecology. Non-climate drivers such as infrastructure development and population growth can have multiplicative and additive effects on the impacts of climate change.

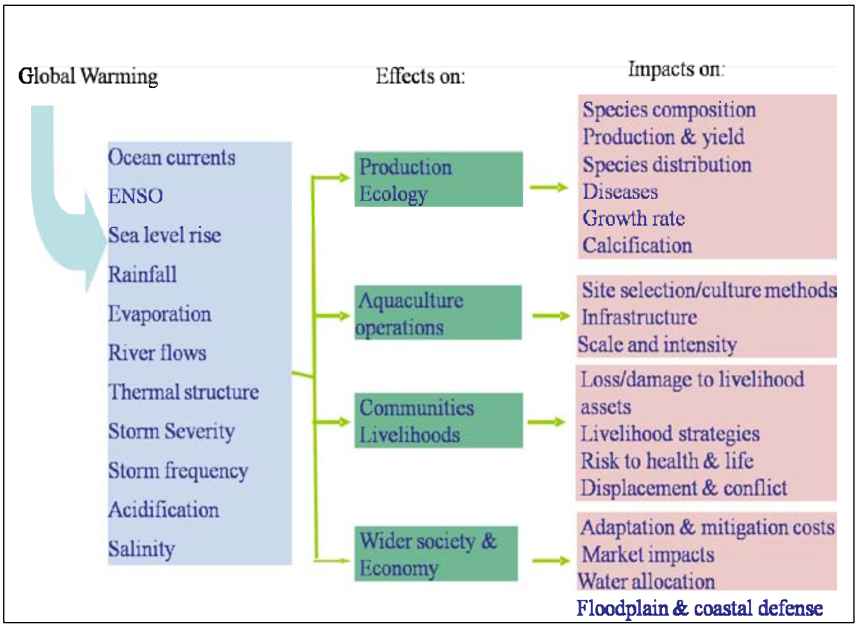

Figure 2.29 Global warming and capture fisheries: impact pathways
Note: This figure is not intended to be comprehensive but to give examples of potential impact pathways.
Source: Modified from Badjeck *et al.* (2009a).

Table 2.5 Main characteristics of aquaculture production systems in Viet Nam and implications of impacts and adaptation to climate change

Characteristics of aquaculture production systems	Impact and adaptation
There are two main aquaculture systems based on freshwater and brackish-water environments, with mariculture (in the marine environment) as a minor subsector.	The nature of climate change (CC) impacts on these environments is different; hence, the exposure of these main systems is also different.
Aquaculture production is at different levels of intensity and capitalization and involves different levels of participation, ranging from large numbers of small-scale producers to relatively small numbers of highly commercialized enterprises.	Vulnerabilities and adaptive capacities in the context of climate and other global drivers of change vary substantially with aquaculture production systems.
There is a diversity of aquatic species and production systems for freshwater and brackish-water aquaculture, fitting into different agro-ecologies, ranging from purely aquaculture activities to integrated production (e.g. within rice and mangrove areas).	Unlike single species commodities, such as rice or livestock animals, this diversity of aquaculture products and systems makes it potentially an adaptable sector as environmental conditions change due to CC.
Aquaculture, in various forms, competes with or complements other food production systems particularly in the use of water resources, in both freshwater and brackish-water environments.	Availability and management of water resources for aquaculture and other uses under CC scenarios is crucial, underscoring the observation that "…as much as CC mitigation is about energy, CC adaptation is about water" (START, 2009)[1]
Aquaculture is a dynamic and volatile sector that is subject to economic booms and busts, particularly the export-oriented commodities that are particularly susceptible to global fluctuations in demand (and hence prices) and international pressure on product quality, production standards and food safety regulations. Vietnamese producers as well as the government are highly market-responsive.	For planners, "climate is not the only change around" (START, 2009)[1]; CC is regarded as a slow variable. Other drivers, with shorter-term and more obvious impacts, are of greater concern within the 10–15 year time horizons for planning of the aquaculture sector. These include market-related drivers and impacts of upstream development, particularly hydropower development in the Mekong River Basin.

[1] www.water.tkk.fi/English/wr/research/global/material/water&cc_2009_policy_brief
Source: Badjeck *et al*., 2009b.

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2.5 Aquaculture and climate change

Introduction

The evidence that the climate of the earth is changing profoundly due to the activities of humankind is becoming increasingly stronger. The implications of climate change for humankind are still not fully understood or, indeed, universally accepted. The actions needed to mitigate climate change and to prepare society, particularly its most vulnerable members, have also not been properly considered, let alone implemented.

The present paper focuses on aquaculture, the farming of aquatic organisms. Over the past two decades, aquaculture has consistently been the fastest-growing food production sector in the world (FAO, 2009), and now accounts for half of all fish consumed. Worldwide, it generates tens of millions of jobs, directly and indirectly. Here, we consider the interactions between aquaculture and climate change, beginning with a consideration of how climate change is likely to affect the aquatic physicochemical environment and ecology, and how this in turn affects aquaculture. Using a vulnerability framework, we analyse how increased exposure to climate-related hazards is likely to affect the aquaculture value chain. We then assess aquaculture's contribution to climate change. We consider priority actions needed to mitigate the effects of aquaculture on – and to promote adaptation to – climate change, ending with some specific recommendations. Where possible, we make specific reference to the RNEA.

Impacts of climate change on the physical environment and ecology

Our best estimates of how the climate in the Region is likely to change between now and the end of the present century is more fully considered elsewhere in these proceedings. In sum, and ignoring topographical influences on microclimate, we can expect the climate in the region to become increasingly hotter and drier. The impacts of climate change on the aquatic physical environment and ecology are summarized in Figure 2.30. Seawater temperatures will increase. Combined with sea-level rises, changes in inshore salinities and in wind speeds and direction, currents and seawater mixing patterns can be expected, changing the distribution of species, aquatic productivity and the incidence of harmful algal blooms. Coastal areas and estuaries are likely to see the greatest changes in biophysical conditions and ecology. Inland, changes in the levels and pattern of precipitation are likely to increase the incidence of flooding and affect groundwater and surface water reserves. Temperature rises will increase evaporative water losses, change stratification and mixing patterns of lakes, aquatic community composition and aquatic productivity (for reviews, see Handisyde *et al*., 2006; Allison, Beveridge and van Brakel, 2009; Brierley and Kingsford, 2009; Cheung *et al*., 2009).

Climate change – aquaculture interactions

It is increasingly recognized that social, economic and ecological systems are dynamic, interacting and interdependent (Folke, 2006). Interactions between climate change and aquaculture are two-way – aquaculture contributes to climate change, and climate change affects aquaculture. The impact of the interactions on linked social-ecological systems, however, must be considered in the context of other pressures: changes in population size and demographics, environmental degradation, market, globalization, energy prices, health and economic recession.

Impacts of aquaculture on climate change

A century of abundant, inexpensive fossil fuels has fostered energy-intensive food production and trade. Contemporary food production systems consume many times more energy than they produce (Pimentel and Pimentel, 2008). It is largely through energy consumption, and the resultant release of GHGs, that aquaculture affects climate change.

Life cycle analysis (LCA) is a process, developed in the early 1960s, to evaluate the environmental impacts of a product or service (Hendrickson, Lave and Matthews, 2005) and can be readily applied to estimate the global warming potential (GWP) of different types of aquaculture. An LCA involves the development of a model of the particular aquaculture process, in which boundaries are defined (e.g. is the analysis concerned only with the culture of a particular aquatic plant or animal or should it also consider upstream and downstream activities such as the production and transport of feeds to the farm, post-harvest processing and transport of products to markets?). An inventory is produced of the energy associated with different upstream, on-farm and downstream processes, and the impacts quantified in terms of GWP.

There have been several analyses of the impact of aquaculture on climate change (e.g. Ellingsen, Olaussen and Utne, 2009; Pelletier *et al*., 2009). Among the more recent is that by Henriksson (2009), who examined the GWP (in terms of kilograms of CO_2 per tonne of production) of different types of Asian aquaculture. Confining his analyses to upstream and on-farm processes, he determined that the GWP of shrimp and fish culture is greater than that of oyster farming, while the GWP of extensive fish farming is less than that associated with more intensive aquaculture practices. For shrimp and fish culture, the greatest GWP was found to be generally linked to feed use; the exception was for very intensive *Pangasius* catfish farming systems in the lower Mekong River, where pumping accounted for the greatest proportion of GWP. However, Henriksson's analysis did not account for the GWP associated with land clearance (e.g. mangroves) for ponds or consider the GWP associated with carbon trapped in organically enriched aquaculture pond muds (for further discussion, see Bunting and Pretty, 2007; Downing *et al*., 2008;). His calculations also excluded post-harvest processing and transport to markets, which in the case of exported processed aquaculture products may greatly increase – and indeed account for most of – the GWP.

Impacts of climate change on aquaculture

Impacts of climate change on aquaculture are summarized in Figure 2.30. Some of the impacts will manifest themselves via climate-change-induced modifications to the aquatic physicochemical environment and ecosystem structure and function; others, such as increased storm frequency and intensity, will have a direct impact on aquaculture systems and operations. Sea-level rise will change the availability of sites for coastal aquaculture. Within limits, increases in temperature may stimulate growth and production, beyond which growth and food conversion may suffer, and stress and susceptibility to pathogens increase, depressing production and increasing production costs. Certain areas may thus become more suitable for aquaculture, others less so, as a study of impacts of climate change on Norwegian aquaculture indicates (Lorentzen and Hannesson, 2006). Acidification of the seas will reduce the rate of calcification of molluscs, slowing mollusc growth and reducing production. Reduced rainfall in the region, combined with population growth, will reduce availability and, possibly, increase the costs of using freshwater for aquaculture production (Dugan *et al*., 2007; Nguyen Khoa, van Brakel and Beveridge, 2008). Extreme weather events are predicted to increase, increasing the vulnerability of marine fish cages, ponds, shellfish rafts and longline production systems to damage (Handisyde *et al*., 2006; Brierley and Kingsford, 2009).

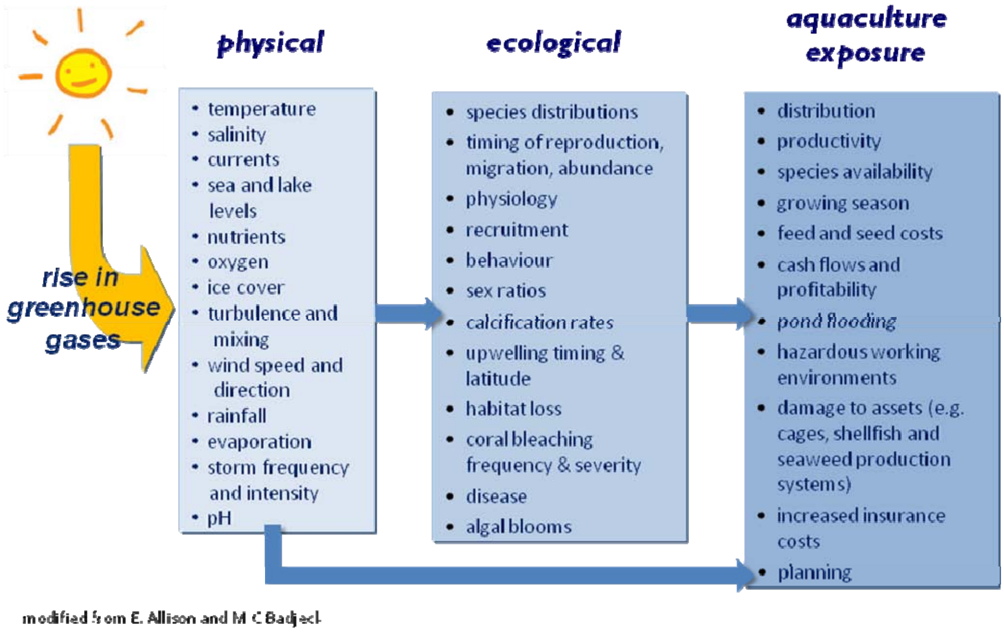

Figure 2.30 Impact of climate change on the biophysical environment of aquatic ecosystems

A vulnerability framework is useful in determining potential and realized vulnerability at a range of scales (Figure 2.31). Individuals whose livelihoods are most exposed to climate change, e.g. those who live in low-lying coastal areas and work as fishers or aquaculture labourers, and who are particularly sensitive to impacts through lack of assets, social marginalization or poor health, are likely to be among the most vulnerable. However, if for example, the individuals who are potentially most affected by virtue of exposure and sensitivity are young, have had a reasonable education, belong to well-organized producer organizations and are supported by strong institutions with well-considered policies, then they are more likely to be able to adapt to the impacts of climate change than those who lack such adaptive capacity.

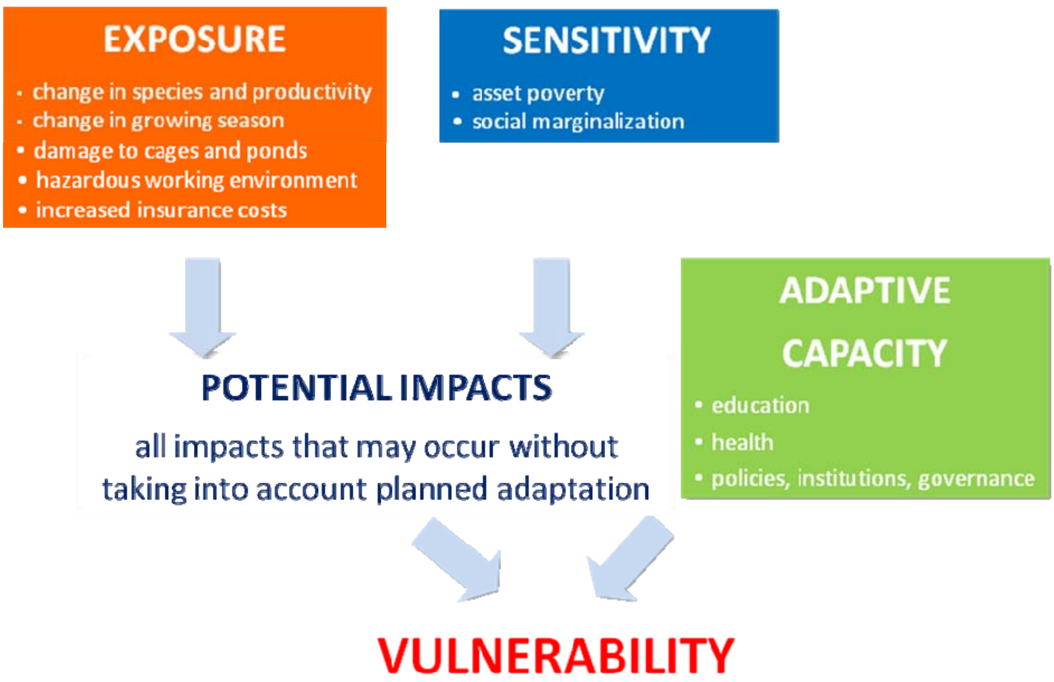

Figure 2.31 A vulnerability framework to determine how exposure and sensitivity interact to determine potential impacts and how, when considered in conjunction with adaptive capacity, these translate into vulnerability of individuals, communities or society

A value-chain approach should be adopted to fully assess the vulnerability of aquaculture to climate change. Aquaculture producers are dependent on a range of inputs, including seed and feed. The availability and prices of the raw materials used in aquaculture feeds, for example, are dependent upon climate change and other shocks. Aquaculture uses 85 percent of global fish oil and 50 percent of global fishmeal supplies (FAO, 2009). The El Niño Southern Oscillation, whose frequency and severity are affected by global warming (Collins *et al*., 2005), determines the productivity of the coastal Pacific ecosystems of Peru and Chile, upon which much of the world's industrial fisheries depend. Availability and price of other key ingredients, such as soybean, will depend upon weather-determined harvests and changing demands for biofuels. Post-harvest processing and market chains tend to be highly energy-intensive and thus sensitive to energy prices (Pimentel and Pimentel, 2008).

The vulnerability of the value chains of various types of aquaculture will have significant effects on fish-related aspects of food security. We can anticipate changes in the availability of various farmed aquatic products as aquaculture production options change in response to climate change. The stability of supplies can be expected to be disrupted as a result of increased seasonality of production and varying supply chain costs. Access to fish for food will change as other foods become more or less affordable. Farmed fish may well be utilized in different ways, in response to climate-induced changes in availability; for example, farmed tilapia, which are currently widely available in Egyptian markets, may become less accessible in the future if value chains shift towards supermarkets in order to try to satisfy the growing demand from middle-class consumers (see De Silva and Soto, 2009).

As may be anticipated from the vulnerability framework (see Figure 2.30), aquaculture-related food security will be most vulnerable where exposure is greatest (e.g. in areas with greatly increased/decreased rainfall and increased temperatures, increased storm frequency), where there are substantial numbers of poor people with livelihoods dependent on degraded environments (i.e. are highly sensitive) and in parts of the world with poor governance and no extreme weather adaptation programmes. Consider, for example, the Mekong Delta, which is particularly exposed to sea-level rises (Adger, 1999). The Mekong Delta has one of the largest aquaculture industries in the world, producing an estimated 1.5 million tonnes of farmed *Pangasius* catfish, worth an estimated USD1.5 billion and upon which some 200 000 livelihoods are dependent.

Mitigation and adaptation: tackling aquaculture – climate-change impacts

Two strategies are needed: mitigation of aquaculture impacts on climate change; and building adaptation of the aquaculture value chain to climate change.

Although the GWP of aquaculture is relatively small in relation to other food-producing sectors, mitigation measures are nonetheless essential. The focus should be on reducing the most energy-dependent activities: on-farm use of energy for pumping, feeds and feeding, post-harvest processing and transport to markets. However, coastal areas that sequester and store large amounts of carbon, such as mangroves and sea grass meadows (Chmura *et al*., 2003; Nellemann *et al*., 2009), should be avoided as aquaculture sites. Aquaculture pond sediments can also accumulate substantial amounts of carbon, which must be handled carefully in order to minimize GWP (Bunting and Pretty, 2007; Allison *et al*., 2009). In pilot trials in the Nile Delta, crops of winter wheat have been successfully grown on pond sediments after fish have been harvested, the stubble flooded at the start of the following aquaculture season boosting fry and fish growth (A. Nasr Allah and D. Kenawy, personal communication).

The vulnerability framework is particularly useful in identifying the principles and actions that should be taken to reduce the vulnerability of aquaculture to climate change: reduce exposure and sensitivity, and build adaptive capacity (see Figure 2.30). Some of the solutions are technical; for example, climate forecasting and modelling can be used to estimate wave climate and currents and to identify appropriate aquaculture technologies (Perez, Telfer and Ross, 2003; Beveridge, 2004). However, many of these technologies are considerably more costly to develop and operate and may be unsuitable for some species, casting doubt on their economic viability, while construction of climateproof cages and other systems is likely to be associated with increased GWP. Other technological solutions include, for example, substituting fishmeal with vegetable protein and developing diets and feeding practices that optimize use of increasingly scarce and expensive marine lipids. It may also prove possible to selectively breed strains of fish that better convert vegetable oils into n-3 highly unsaturated fatty acids (HUFAs). Adoption of an innovation systems approach, which focuses on the flow of technology and information among people, enterprises and institutions, may improve the identification and help strengthen the implementation of innovation.

Adoption of aquaculture can also help to build sustainable livelihoods. In Malawi between 2000 and 2005, some 5 000 smallholders adopted aquaculture. Analysis of performance has shown that farmers grew a wider range of crops, recycled more on-farm wastes, and in drought years experienced smaller decreases in production than smallholders who did not have a farm pond (Dey *et al*., 2007; 2010).

Conclusions and recommendations

Aquaculture both contributes to and is vulnerable to climate change. Climate change will interact with other pressures, such as population growth, changes in markets and trade barriers and energy prices, to affect aquaculture and aquaculture-related food security. In order to assess impacts, a value-chain approach is essential. There will be winners and losers, with present centres of aquaculture production conceivably moving away from particularly hot and dry regions. Impacts will be disproportionately felt among different sectors of society, those with greatest sensitivity and least adaptive capacity and being most dependent on degraded environments – i.e. the socially marginalized, poor farmers, fishers and consumers – being most vulnerable. Adoption of aquaculture has also been shown to help build resilience to the effects of climate change.

A vulnerability framework, which is consistent with the EAF being promoted by the FAO and partners, offers a useful perspective to identify and prioritize actions (see elsewhere in these proceedings).

Aquaculture, although a relatively small contributor to the generation of GHGs, must nonetheless minimize its GWP by not exploiting areas with high amounts of sequestered carbon, by designing better feeds and optimizing their use, by taking care of the fate of organically enriched fish-pond sediments and by minimizing energy consumption associated with post-harvest processing, transport and marketing. Evidence from other sectors suggests that mitigation may not be that costly. However, it is likely that fiscal and economic incentives will be introduced to encourage such changes, although ultimately it will be consumers who, through choosing what to eat, may play the more important role in promoting mitigation.

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3. SUBREGIONAL REVIEWS

The subregional reviews were submitted by experts from various subregions of the Near East and North Africa, covering all of the major waterbodies in the Region. Their titles are:

- Climate change and ecosystem-based approach to fisheries and marine aquaculture for Mauritania and Morocco, by A. Orbi (INRH), S. Zizah (INRH), K. Hilmi (INRH) and M.Y. Laaroussi (Ministry of Agriculture and Fisheries);
- The ecosystem approach to fisheries and aquaculture for the Southern and Eastern Mediterranean, by M. Belhassen (INSTM);
- The ecosystem-based approach to fisheries and aquaculture for the Red Sea and Gulf of Aden, by M.M.A. Zaid (Al-Azhar University);
- Adapting to climate change: a review on the ecosystem approach to fisheries and aquaculture in the RECOFI region, by H. Negarestan (IFRO).

3.1 Climate change and the ecosystem-based approach to fisheries and marine aquaculture for Mauritania and Morocco

Introduction

Four large upwelling ecosystems border the western boundary of the African continent. In the Atlantic, the economic exclusive zones (EEZs) of the Gambia Morocco, Mauritania and Senegal are part of the Large Marine Ecosystems of the Canary Current.

Upwelling ecosystems provide more than 40 percent of world fisheries catches while representing less than 3 percent of the ocean’s surface. Coastal upwellings are induced by winds that cause the movement of cold deep ocean water, rich in mineral salts, to the surface. The source of high biological production, they are nevertheless subject to significant interannual and interdecadal fluctuations (Cury and Roy, 1989; Binet, 1997; Demarcq and Faure, 2000). The Canary Current sustains the highest primary production among the four global upwelling systems; however, its fisheries production is much less than in the Humboldt system (see Table 3.1).

Table 3.1 Primary production and surface occupation of the four upwelling systems in the world

	California	Humboldt	Benguela	Canary
Annual primary production (gC/m^2)	388	269	323	732
Surface (km^2)	$0.96*10^6$	$2.61*10^6$	$1.13*10^6$	$0.81*10^6$
Approximate annual mean total catch (tonnes)	1 000 000	10 000 000	1 500 000	2 000 000

Source: Adapted from Longhurst *et al*., 1995.

These ecosystems are undergoing the effects of climatic change and those of the reorganization of world fisheries, which may lead to significant modifications in their own organization. The management of these ecosystems must be conceived within the wider framework of coastal development in bordering areas. In the Canary Current upwelling system, for example, there is a need to know the frequency of climatic systems variability, acknowledging the significant degrees by which small pelagics fluctuate in this area.

Coastal upwelling along the eastern boundary of the North Atlantic subtropical gyre follows the north–south migration of the atmospheric pressure systems, occurring only in summer at the northern extreme, all year (although more intense in summer) in its central portion, and only in winter south of Cape Blanc (Wooster, Bakun and McLain, 1976 cited by Aristegui *et al*, 2009).

Along most of the Moroccan coast, the subregional upwelling is year round and strongest in late summer (Wooster, Bakun and McLain, 1976; Orbi *et al*., 1998; Makaoui *et al*., 2005). The oceanography over the Mauritanian shelf (water depths < 200 m) represents a dynamic balance between flow from the north and flow from the south, largely controlled by atmospheric variability (Mittelstaedt, 1991; Hagen, 2001) with the seasonal strengthening of the Azores High and associated north–northeast winds. The trade winds thus intensify south of 20°N in spring and north of 26°N during summer. Between 20 and 26°N (Cape Blanc to Cape Bojador), a strong alongshore wind blows all year round. As a result, the offshore Ekman transport and associated upwelling are permanent between 20 and 26°N, and seasonal during winter and summer south of 20°N and north of 26°N, respectively.

Fisheries and aquaculture in Morocco

Introduction

Morocco, located in the northwest of Africa, has a coastline 3 000 km long in the Atlantic Ocean and 500 km long in the Mediterranean Sea. It has different influences: the Atlantic Ocean, the Mediterranean Sea, the Sahara region, and the Atlas Mountain range. During the last decade, the climate in Morocco has experienced a clear change; it is arid to semi-arid in the majority of the country. It is governed by the North Atlantic Oscillation (NAO). It can be divided into three major subareas (Figure 3.1).

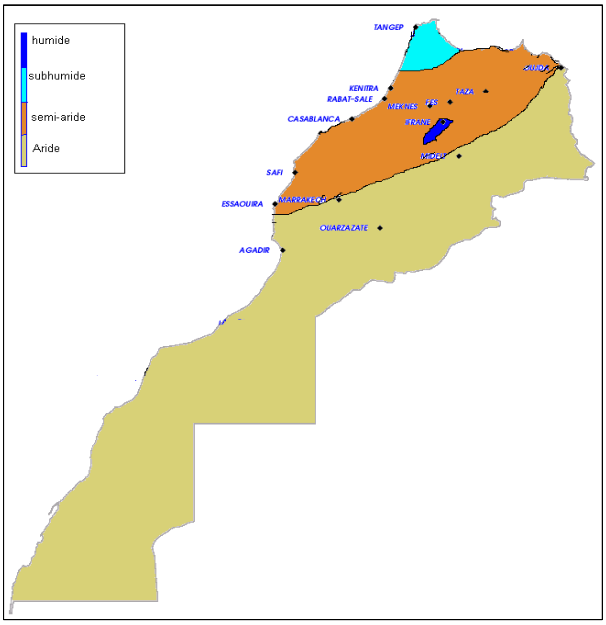

Figure 3.1 Climate in Morocco, 1986–2005
Source: Direction de la Meteorologie Nationale (DMN), Morocco.

Among the major climate change impacts are a reduction in water resources, a reduction in agricultural yields, and a rise in sea levels.

Fisheries sector

Marine fisheries include the following activities:

- High sea fisheries are practised for cephalopods and crustaceans fisheries mainly for frozen products, with vessels of more than 300 Gross Register Tonnage (GRT).
- Coastal fisheries, an activity undertaken by a coastal fleet, are composed of coastal sea bottom trawlers and purse seining and wooden lining vessels.
- Artisanal fisheries use boats of less than 2 GRT for fresh fishing.
- Coastal activities also involve fishing for algae, corals, shellfishes and echinoderms.
- Almadraba tuna is a practised for tuna fishing (mainly bluefin tuna).

- Industrial fisheries involve preserved and semi-preserved food, inland freezing, conditioning food-preserving industries of fresh fish, fishmeal, fish oil and marine algae processing.

The main fish stock resources exploited by the national fleet are pelagic species. Small pelagics fished consist of: sardine (S*ardina pilchardus*), sardinella, mackerel, chub mackerel (*Scomber japonicus*), and anchovy (Figure 3.2). Large pelagics include: bluefin tuna, melva, bonito and swordfish. Small pelagic production represents 70–80 percent, with sardines dominating the catches. However, the contribution of the pelagic production is only 20 percent of the total production value (Figure 3.3). Demersal species are composed of crustaceans, cephalopods, white fish and shellfish.

Seven percent of catches comes from the Mediterranean, 9 percent from the North Atlantic, 30 percent from the central part of the Atlantic, and 55 percent from the South Atlantic (Département des Pèches Maritimes [DPM], 2009).

In 2009, approximately 36 percent of fish products from coastal and artisanal fisheries were used for local consumption, 11 percent for canning, 24 percent for freezing, 27 percent for fishmeal and fish oil industries, 1 percent for salting and 0.6 percent for bait (2008 and 2009 statistics from the Office National des Pêches [ONP]).

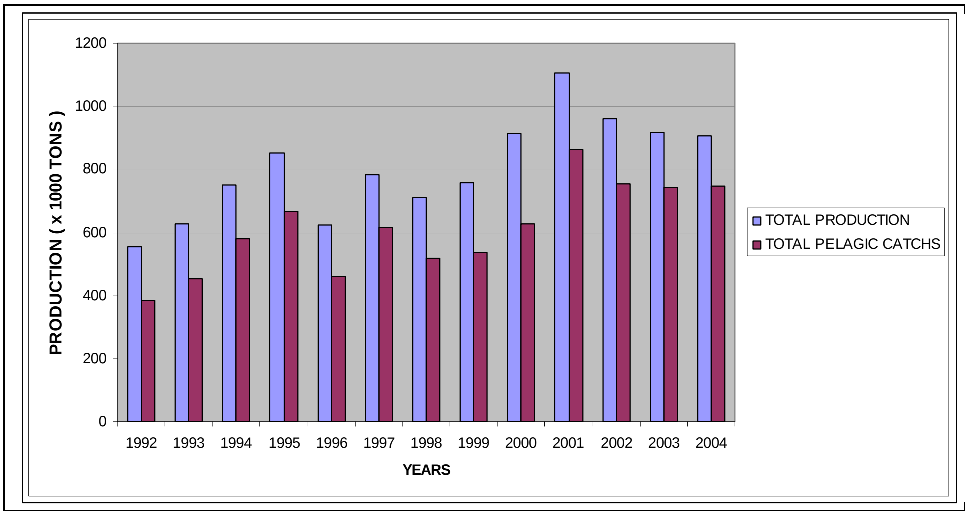

Figure 3.2 Total catch and pelagic catch contribution, Morocco
Source: ONP, various years.

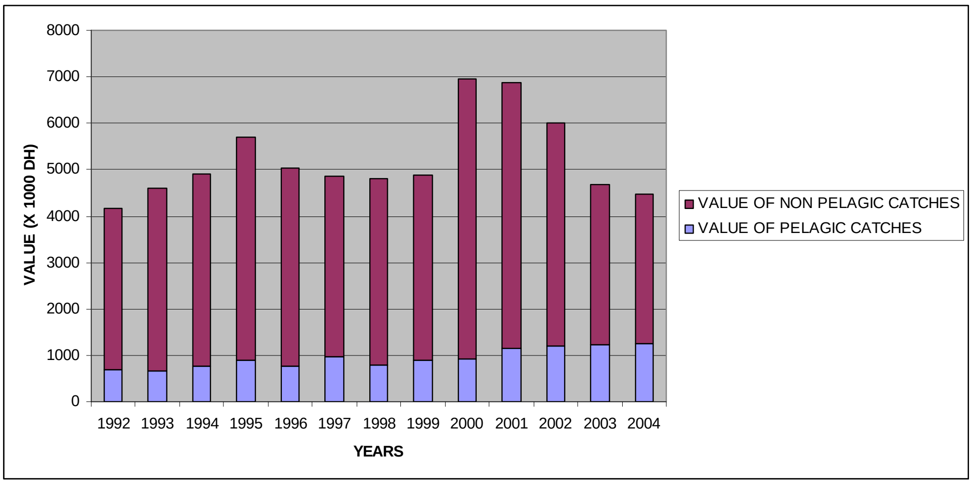

Figure 3.3 Fisheries production value and pelagic contribution value, Morocco
Source: ONP, various years.

Aquaculture subsectors
Marine aquaculture began about 50 years ago when oysters were first bred in the Atlantic Oualidia Lagoon, south of Casablanca, producing approximately 200 tonnes. The first intensive sea fish breeding trials were undertaken in the 1980s on Mediterranean sites suitable for this kind of aquaculture.

Inland aquaculture began in 1924 with the establishment of the fish farming station at the Middle Atlas Lakes. The original purpose of the facility was to promote angling as a sport, by breeding and releasing fingerlings with a high nutritional and economic value, particularly into the Middle Atlas Lakes and various dams and impoundments. After the 1980s, following communities of professional fishers that had settled in these environments, the government redirected its work towards fish breeding for food production using intensive systems, in natural and artificial ponds.

Private enterprise took off rapidly after the 1990s, with the guaranteed support of Morocco's High Commissioner for Water, Forests and Combating Desertification (HCEFLD). A few private aquaculture units are still in operation today and continue to raise eels, trout, common carp and Nile tilapia. Total aquaculture production from 1990 to 2007 did not exceed 2 500 tonnes per year (Figure 3.4).

In 2004, aquaculture production in Morocco was 1 690 tonnes, which only accounted for 0.19 percent of total national fish production. Marine aquaculture output was 788 tonnes, or 47 percent of aggregate national aquaculture production, mainly of European seabass and gilthead seabream, which accounted for 91 percent of total production. These two species were intensively farmed in floating cages in the lagoons, and in open water.

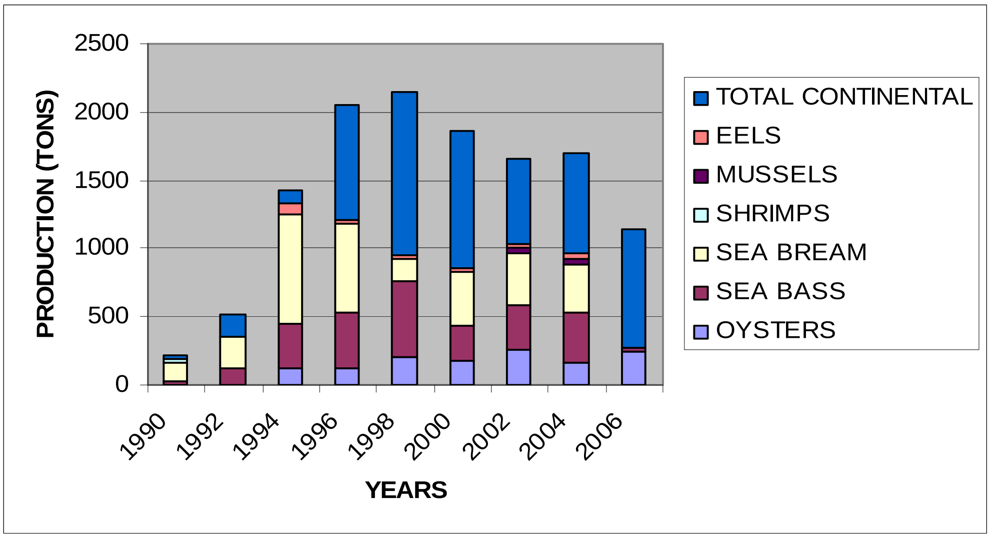

Figure 3.4 Aquaculture production in Morocco
Source: Département des *Pêches* Maritimes, various years.

In 2002, reported domestic aquaculture production was 1 670 tonnes. Seabream accounted for about 22.6 percent, seabass 19.5 percent and cupped oysters 15.2 percent. The production of these three species has remained stable over the past few years.

However, carp production (common carp, grass carp, and silver carp) has fallen by 65 percent below 1999 levels, when production reached 1 400 tonnes. Rainbow trout production is less than 100 tonnes/year. However, 2002 was a good year for Mediterranean mussel production, a commodity that has become increasingly important in recent years.

Importance of the fisheries sector to the economy
The contribution of fisheries to the economy is 2–3 percent of GDP. The sector provides 170 000 direct jobs (1.5 percent of the active population) and 490 000 indirect jobs (source of income for 3 million people). It generated Dh16.3 billion in turnover in 2007 (of which 70 percent was export sales), and 1 million tonnes are produced per year. Morocco has 22 fishing ports, and there are 22 managed landing points. The fishing fleet consists of 344 high seas vessels and 1 835 coastal vessels. The artisanal fleet is composed of 14 225 boats.

After September 2009, Halieutis was adopted by the Government as a new strategy for the fisheries and aquaculture sectors in Morocco. This strategy considers that the fish resource is a sustainable and natural heritage and that aquaculture is a strong growth driver. Fishing ports should be structured and equipped. Inland valorization of catches should be initiated. A controlled flow should be carried out throughout the value chain.

An integrated sectoral approach is suggested to reach competitiveness, sustainability and performance. The strategy is to:

- build and share scientific knowledge;
- develop fisheries on the basis of quota;
- adopt and modernize the fishing effort;
- develop aquaculture;
- dedicate port areas to fishing and effective management;
- enhance the attractiveness of the fish markets;
- structure and revitalize the market around the wholesale markets and retail;
- develop infrastructure and equipment for landing;
- support guidance on industrial growth markets;
- facilitate access to industrial raw materials;
- create three clusters in the north, centre and south.

Tools for the implementation of these objectives are:

- National Committee for Fisheries;
- National Agency for Development Aquaculture;
- Valorization Center of Fishery Products;
- Employment Observatory of the Fisheries Sector.

Generally speaking, aquaculture makes a negligible contribution to Morocco’s national economy.

Fisheries and aquaculture in Mauritania

Introduction
Mauritania is a vast country of the Sahel located between 15°N and 27°N, covering 1 030 700 km^2. Its coast of about 800 km has a rich biodiversity, Arguin Banc serving as an example of a biological reserve. Mauritania has very little aquaculture activity.

The climate of Mauritania is governed by three influences:

- The Azores anticyclone centred over the southwest of the Azores archipelago; the sea breeze from this anticyclone blows permanently onto the north and the northwest coast of Mauritania.
- The Saint Helena anticyclone or monsoon centred on the South Atlantic; it blows from the south or southwest. It is responsible for summer rainfall.

- Anticyclonic cells that settle on the Sahara in winter and migrate north in summer to give birth to the Saharian depression. The Harmattan derived from these anticyclonic cells is cool and dry during the winter and hot and dry in summer.

Taking into account the rainfall and its distribution during the year, Mauritania can be divided into three subclimatic regions:

- In the extreme south, a tropical dry climate (Sahel–Sudan type) characterized by eight dry months (rainfall greater than or equal to 400 mm).
- In the centre, a semi-desert climate (Sahel–Saharan type) characterized by a high temperature range and rainfall between 200 and 400 mm.
- In the north, a climate like the Sahara characterized by lower rainfall. More than 75 percent of the country is desert.

There are four ecological zones: the arid zone, the Sahel (the Sahelian zone covers a strip of 200 km in the south), the Senegal River area (where the potentially largest forest is located on 3 percent of the total area) and the coast (Figure 3.5). According to FAO, the arid climate zone has increased: the 150 mm isohyets have come to settle about the location of the 250 mm isohyets, an expansion of an additional 150 000 km² of desert.

Figure 3.5 Climate in Mauritania

Surface waters are mainly from the Senegal River and its tributaries: the Karakoro River and the Gorgol River. The country has significant groundwater resources: some of the most important aquifers are located in desert areas far from urban centres and potable water remains a crucial problem. Nouakchott is particularly affected by the shortage of drinking-water.

Fisheries sector

Fisheries in Mauritania are synonymous with marine fisheries. The continental and river segment remains very marginal and is confined to the local market. Aquaculture does not exist, with the exception of some experiments that have been undertaken with limited range related to tilapia in the south of the river and oysters in Lévrier Bay. Industrial fisheries account for 90 percent of catch, of which a great part is not actually landed in Mauritania (fishing agreement and free fishing licences of the pelagic species). The landing in Mauritania is about 120 000 tonnes coming from artisanal fisheries (fresh fish), and 20 000 tonnes of fish from industrial fisheries is generally frozen or under ice (Figure 3.6).

More than 72 species of economic value are caught in Mauritania. The main species are:

- cephalopods (octopus, squid, cuttlefish);
- crustaceans (green lobster, pink lobster, tiger shrimp, king prawn, crab, sea urchin);
- demersal fish (hake, sea bream, sole);
- small pelagic species (sardinella, sardines, chub mackerel, mackerel, pelagic squid);
- tunas (swordfish, yellowfin tuna);
- oysters and hardshell clams.

Almost all of the landings in Mauritania are made up of noble species such as cephalopods, black drum, sea bream and sole. The amount landed in Mauritania is mainly made up of: 25 297 tonnes of frozen cephalopods; 7 915 tonnes of frozen demersal fish; 5 073 tonnes of frozen pelagics; 1 101 tonnes of frozen shellfish; 80 000 tonnes of fresh fish and cephalopods.

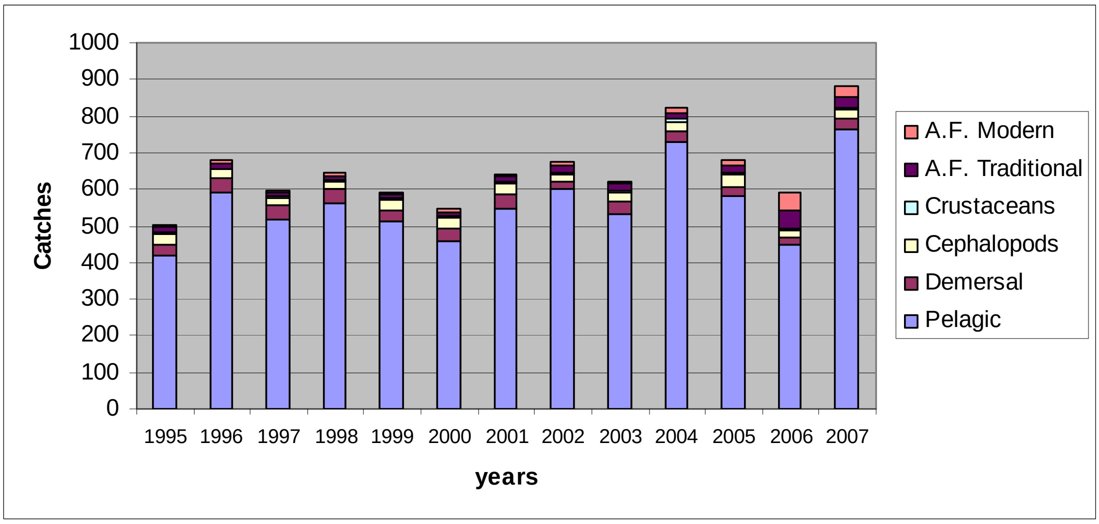

Figure 3.6 Fisheries production in Mauritania

The fishing resources in Mauritania are very diverse and are made up of continental, river and marine resources, which compose the main part of the resources. The main species by type are highlighted in Table 3.2.

Table 3.2 Main fishing resources

Main demersal species	Main pelagic species	Main continental/river species
Cephalopods	Small pelagics	Tilapia
Finfish	Tuna and similar	Danton
Shellfish		Mullet
Hardshell clams		Sardines

In addition, Mauritania has an important stock of algae, which remains unknown and unexploited. The stock of the hardshell clams is currently under evaluation and experimentation for exploitation purposes. The new estimates would be three times more important than what was estimated in the 2003 evaluation.

Aquaculture subsector
There is no aquaculture activity in Mauritania.

Importance of fisheries to the economy
The contribution of fisheries to the economy of Mauritania (including the fisheries agreement between Mauritania and the EU) accounts for 6–10 percent of GDP; it provides 25–30 percent of revenue to

the State budget and generates approximately 30 000 jobs (at sea and inshore), or 36 percent of modern sector employment in the country (strategy for sector development). The overall volume of exports has been declining for several years and many high-value species are in a state of overexploitation (e.g. octopus and shrimp). The incursions of illegal fleets in prohibited areas, the use of prohibited or insufficiently selective fishing gear, intensified competition between artisanal fisheries (increased capture from about 21 000 tonnes in 1995 to 35 000 tonnes in 2005) and industrial fisheries not only threaten the marine environment but also the industry itself and, thus, the livelihoods of those working there.

Mauritania adopted a new strategy for fisheries for 2006–08, with a clear strategic objective of combining the optimization of the sector within the nation’s economy with a sustainable management of the resources and a safeguarding of maritime environment (e.g. risks related to industrial activities in port areas, with maritime transport, and oil exploitation offshore).

The choice of the four strategic issues around which the strategy is articulated demonstrates a solid comprehension of the existing links between economic issues and environmental sector. These issues relate to:

- improvement of governance in fishing;
- improvement of the littoral and environmental governance;
- acceleration of the process of integration of the fisheries sector in the nation’s economy;
- capacity building of governance in the sector.

The project of the maritime environment code worked out in 2006 is focused on prevention and mitigation against the various types of marine pollutions and takes into account risks relating to hydrocarbon accidents through the preparation and the actualization of the POLMAR plan (emergency national plan in the event of accidental pollution by hydrocarbons).

Understanding of possible climate-change impacts in the subregion

The vulnerability of fishery- and aquaculture-dependent communities and regions to climate change is complex, reflecting a combination of three key factors: (i) the exposure of a particular system to climate change; (ii) the degree of sensitivity to climate impacts; (iii) the adaptive capacity of the group or society experiencing those impacts.

Vulnerability varies greatly across production systems, households, communities, nations and regions. Developing policies and strategies to address climate-change impacts on fisheries and aquaculture depends on identifying vulnerable places and people and understanding what drives their vulnerability. This requires vulnerability assessments at multiple scales and taking into account multiple interacting drivers.

Acoustic surveys have been conducted each year since 1995 on board of the research vessel *Dr Fridtjof Nansen* during the recruitment period. Between 1996 and 1997, the stock decreased by one order of magnitude (Figure 3.7) from more than 5 million tonnes of sardines to less than 0.5 million tonnes (Strømme *et al.*, 2004, 2008). The winters of 1995 and 1996 were characterized by a negative NAO index gradient between Iceland and the Azores associated to a weakening of their centre of pressure, which resulted in a less intensive upwelling activity (Benazzouz *et al*., 2006).

Results obtained by Machu *et al*., (2009) show that variability in the sardine stock is partly controlled by the environment via the plankton communities together with the volume of the spawning ground, which fluctuates at seasonal and interannual time scales.

However, other experiments show that sea surface temperature (SST) records from Moroccan sediment cores, extending back 2 500 years, reveal anomalous and unprecedented cooling during the twentieth century, which is consistent with increased upwelling (McGregor *et al*., 2007). The evolution of SST from 1995 to 2000 is demonstrated in Figure 3.7.

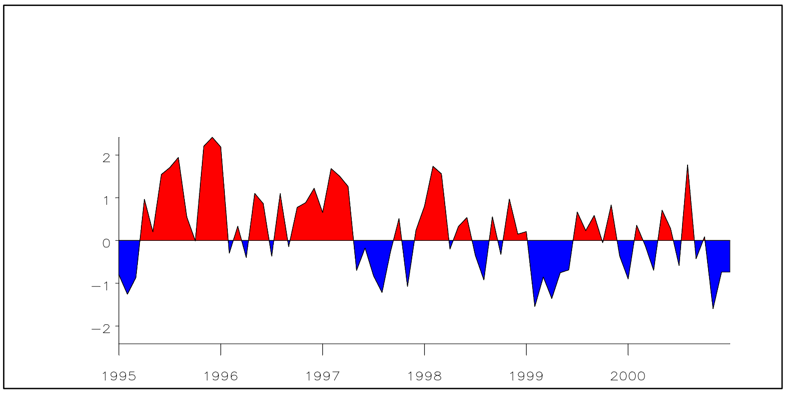

Figure 3.7 Evolution of sea surface temperature anomaly off Cape Blanc (20 °50'N, 17 °30W), 1995–2000

Upwelling off northwest Africa may continue to intensify as global warming and atmospheric CO_2 levels increase. During the past ten years, three major events occurred south of the Moroccan coast (26 °N–21 °N) which are generally accepted (by scientists and policy-makers) to be related to the impacts of climate change (Figure 3.8):

- sardine stock collapse as a natural event (1997);
- sardinella migrating to the north;
- important decline in sardine stock in 2006 (fish with lesions common in 2005).

Biomass estimates of sardines between 16 °N and 29 °N from acoustic surveys by the *Dr Fridtjof Nansen* during November 1995–2003 indicate that there was a biomass decrease in 1997. From acoustic abundance estimation by latitudes from 1995 to 2003 (Figure 3.9), it is apparent that in 1997 there was a decrease in the biomass abundance.

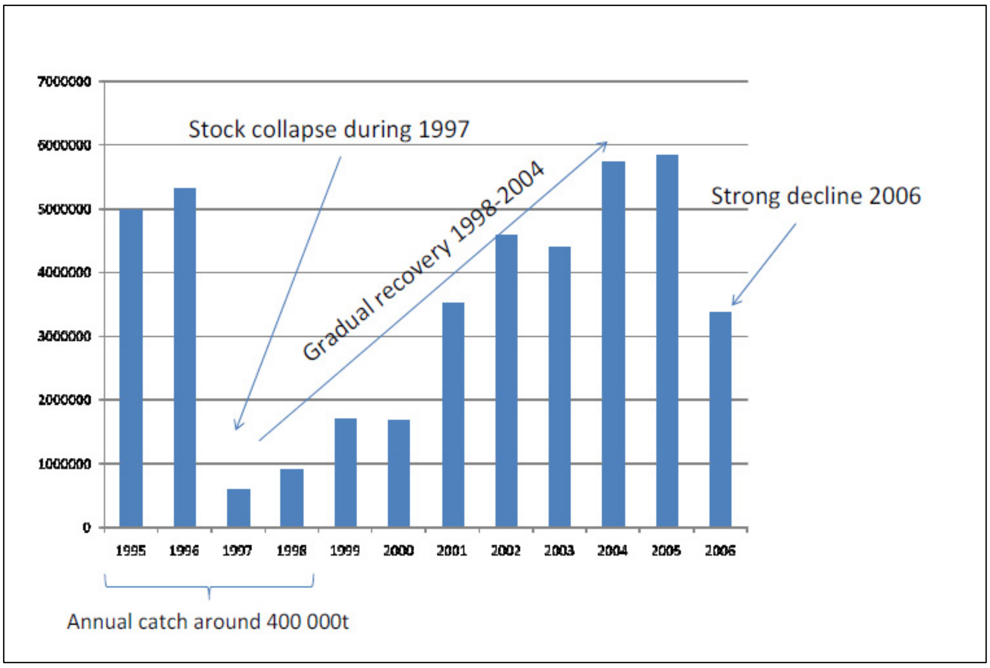

Figure 3.8 Biomass estimation of sardine stock by *Dr. Fridtjof Nansen*
Source: Strømme *et al*., 2008.

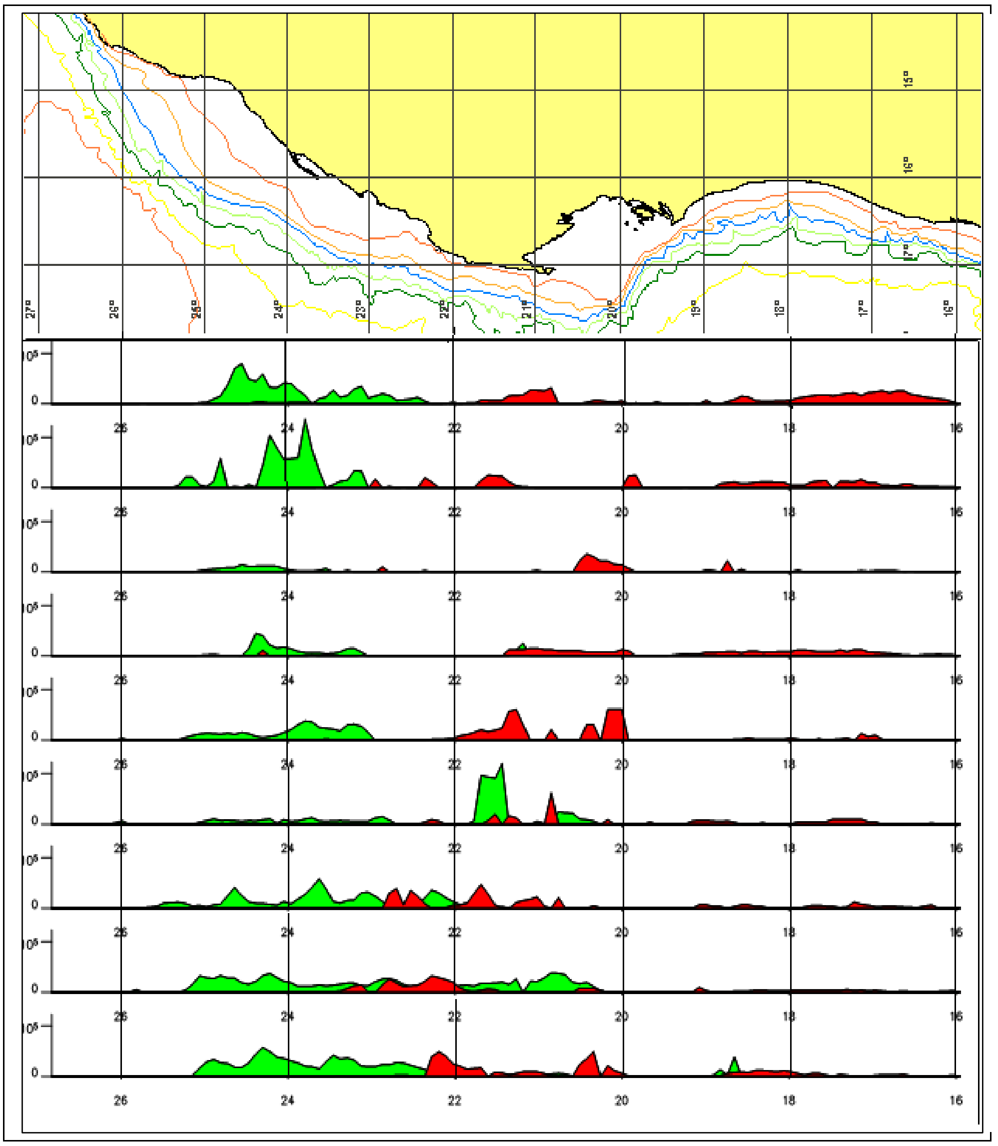

Figure 3.9 Biomass estimation of sardines by *Dr Fridtjof Nansen*
Source: M. Ostrowski, personal communication.

A third event found during the 2005 acoustic survey were some fish with common lesions. Neither bacteria nor viruses were responsible for these lesions. To date, scientists have not solved the enigma of these lesions (see Figure 3.10).

Figure 3.10 Fish with lesions common in 2005

Recommendations

Morocco, in 2009, and Mauritania, in 2006, launched new strategies for their fisheries sectors based on ecological well-being and human well-being. Unlike Mauritania, Morocco integrated aquaculture as a main feature in its strategy. However, in both countries, the economy is highly vulnerable to climate change (Figure 3.11).

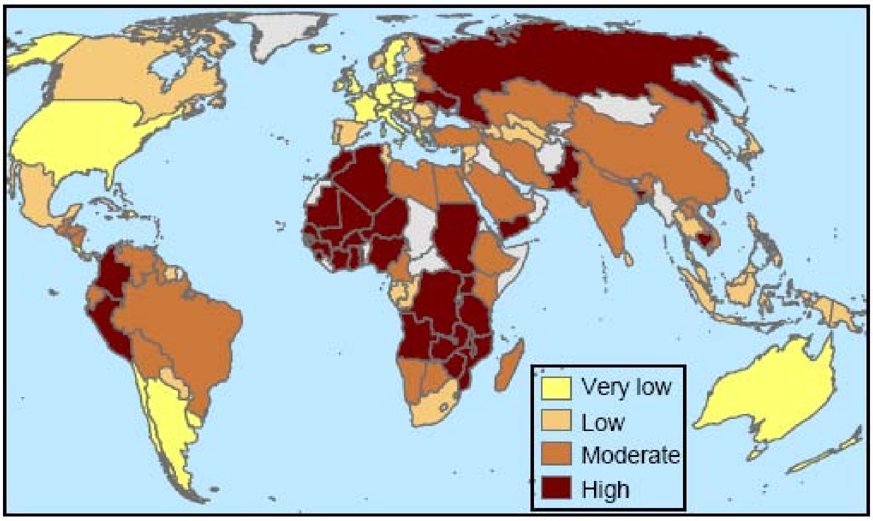

Figure 3.11 Vulnerability of national economies
Source: Allison *et al*., 2005.

It is recommended that a detailed vulnerability study be carried out, with a focus on:

- the nature and degree to which both fisheries production systems and coastal poor populations are exposed to climate change;
- the degree to which national and local economies are dependent on fisheries and, therefore, sensitive to any change in the sector.

These elements will allow both governments to measure the ability or capacity of a system to modify or change to cope with changes in actual or expected climate stress.

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3.2 The ecosystem approach to fisheries and aquaculture for the southern and eastern Mediterranean

Introduction

In the Southern and Eastern Mediterranean Sea, fisheries and aquaculture fishing have had significant effects on livelihoods, employment opportunities and foreign exchange earnings in the countries of the region. In view of overfishing, environmental degradation and anthropogenic impacts on ecosystems, it is essential that some form of effective management plan be drawn up, based on an accurate and relevant scientific approach, to provide for adequate environmental management of the region.

Moreover, the Mediterranean, especially its southern and eastern rims, is likely to be more affected by climate change than most other regions of the globe in the twenty-first century. The temperature increases in the Mediterranean are likely to be above 2 °C and, because of the ecological and socioeconomic characteristics of the areas, the impact will be more marked than in many other regions of the world. The Mediterranean has thus been qualified as a "hot spot for climate change" (Giorgi, 2002). The most vulnerable areas of the Mediterranean are the North African ones bordering desert areas, the major deltas (e.g. the Nile Delta), the coastal zones, as well as socially vulnerable areas and those with rapid demographic growth (IPCC, 2007).

The impacts of the rise in temperature, drop in rainfall, increase in number and intensity of extreme events, as well as a possible rise in sea level, could thus overlap and exacerbate the pressures caused by anthropogenic activities that are already exerted on the natural environment. Through the crucial issue of the scarcity of water resources, the impacts of climate change are fraught with consequences for the fishery and aquaculture subsectors in the twenty-first century, particularly in terms of production and water quantity and quality. In order to minimize the economic losses and damage as much as possible, several adaptation options must be thought out and implemented.

This paper provides a review of the fisheries and aquaculture subsectors in six countries from the southern and eastern Mediterranean. It explains the major trends in these subsectors, highlights their importance to the national economies, and emphasizes the need for a management framework in a context of climate change.

Description of the subregion

The subregion from Algeria to the Syrian Arab Republic is located on the southern and eastern sides of the Mediterranean (Figure 3.12) and is surrounded by Europe to the north, Africa to the south, and Asia to the east. It is about 5.5 million km^2; the coastline extent is about 7 400 km and the continental shelf area is about 230 000 km^2.

In general, the region is under the influence of the Mediterranean climate, characterized by mild wet winters and warm to hot, dry summers. Because of its latitude, the Mediterranean Sea is located in a transitional zone where both mid-latitude and tropical variability are important and compete against each other.

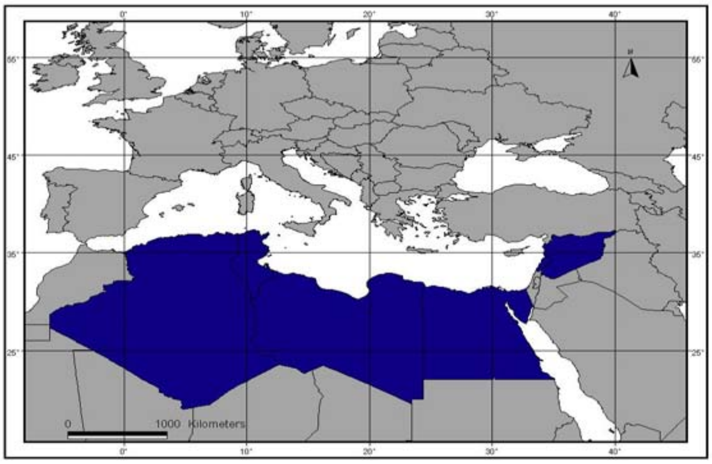

Figure 3.12 Study area, comprising six countries from the southern and eastern Mediterranean

The southern and eastern Mediterranean Sea is characterized by limited water productivity owing to its low nutrient concentrations. However, it hosts one of the richest biodiversities in the world. The freshwater resources are under increasing pressure in terms of both quantity and quality. This is particularly the case for five out of the six countries in the subregion, with the exception of Egypt, where the Nile River supplies the country with important water quantities. The subregion is characterized by the emergence of highly populated societies. Because of the demographic pressure and exploitation of land for agriculture, the subregion presents important anthropogenic effects on the environment. Currently, approximately 140 million people live in these countries. For most of the countries, urbanization is an ongoing process that is changing the socio-economic structures of this region. All these trends are likely to produce contrasts and conflicts in a condition of limited available resources.

Resources and production

Marine fisheries

The fishing activity throughout the southern and eastern Mediterranean has a long tradition. It is characterized today by the dominance of an artisanal (coastal) sector, a timid growing of an industrial sector, and by a large dispersion of fishing and marketing along the coast. The fisheries of the subregion are based on relatively poor resources and often exploited by individuals with low-cost vessels and simple gear. In certain localities of the subregion, fisheries provide an important source of employment and income.

According to the data compiled by FAO on the basis of reports from national authorities and other sources (e.g. regional fishery organizations), Mediterranean fisheries capture production experienced a sharp increase from the 1950s onwards, with a relative stabilization since the 1990s (Figure 3.13). Recent statistics from 2007 show that capture production was about 350 000 tonnes. Algeria, Tunisia and Egypt were the top producing countries (Figure 3.14).

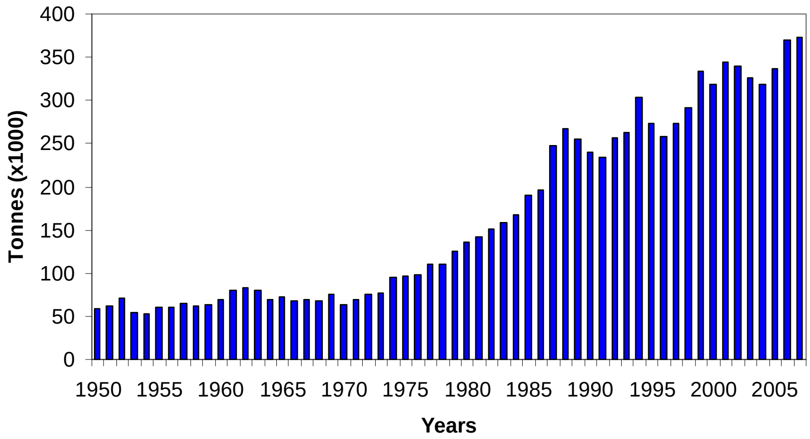

Figure 3.13 Subregional marine capture production

In most countries throughout the region, it is difficult to estimate the state of the stocks because of the absence of surveys to monitor fishing effort. Only inferences based on catch trends are possible. It can reasonably be assumed that, if catches have shown limited increase, it is because of overfishing rather than reductions in the fishing effort. On the whole, it seems unlikely that any underexploited stocks have been left in the region, although some small pelagic stocks can increase suddenly from time to time, possibly owing to temporary environmental conditions. Relatively rich trawling grounds are found in the Gulf of Gabés in Tunisia, the Gulf of Sirte in the Libyan Arab Jamahiriya and off the Nile Delta in Egypt.

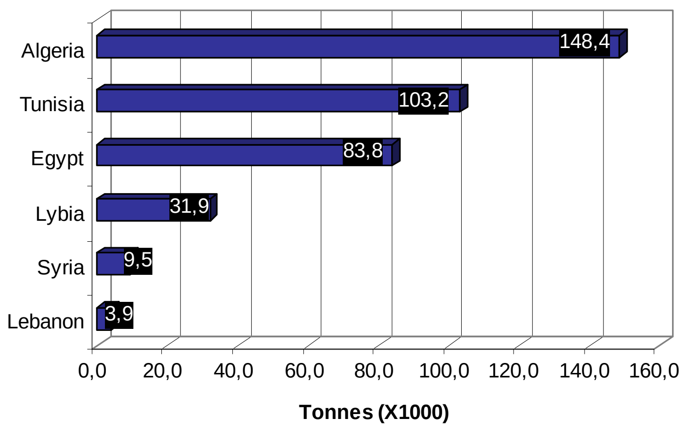

Figure 3.14 Marine capture fisheries: countries production in 2007

Inland fisheries

The present status of inland capture fisheries gives an estimated production of 249 000 tonnes in 2007, while it reached 320 000 tonnes in 2002 (Figure 3.15). Egypt, with about 8 716 km^2 of inland waters, including rivers, lakes, reservoirs and brackish-water lagoons, is the main producing country, representing on average more than 97 percent of the total inland capture production in the subregion. The most economically important species are tilapia species, usually caught by trammel, cast and gillnets.

Figure 3.15 Subregional inland capture production

Aquaculture
There are some similarities between the subregion countries concerning the farmed species and the farming techniques. However, there are significant differences in aquaculture quantities produced by countries. Egypt is the only country that has developed substantial aquaculture activities. Since the end of the 1990s, aquaculture production has substantially increased, with an annual growth rate of about 16 percent (Figure 3.16). Recent statistics from 2007 indicate an aquaculture production of about 650 000 tonnes. Egypt remains by far the largest producer, representing on average more than 97 percent of the total production of the subregion, based almost exclusively on inland aquaculture.

In Egypt, aquaculture is currently the largest single source of fish supply accounting for almost 63 percent of the total fish production of the country with over 98 percent produced from privately owned farms. The majority of fish farms in Egypt can be classified as semi-intensive, brackish-water pond farms. This type of farming suffered a dramatic reduction in numbers during the early 1990s as a result of the competition for land and water from the expansion of land reclamation activities for agriculture. Intensive aquaculture, in earthen ponds, is now developing rapidly to overcome the reduction in the total area available for aquaculture activity. Warm-water freshwater species represent the majority of aquaculture production in Egypt (Figure 3.17) and are almost totally consumed domestically. Production has steadily increased and today contributes significantly to national food security and limits the import of fish. The main constraint for this activity is the limited availability of freshwater (conflicts with agriculture and requirements for domestic water consumption). In order to overcome these constraints, the country is trying to increase the stocking density in this form of fish rearing.

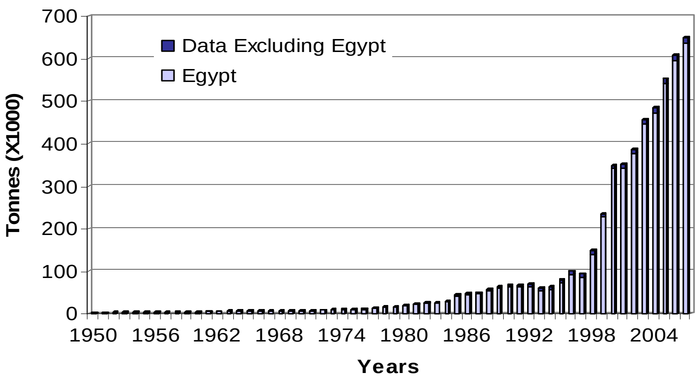

Figure 3.16 Subregional aquaculture production

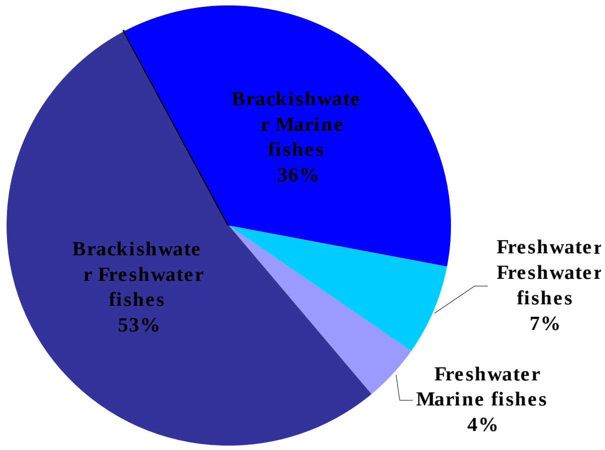

Figure 3.17 Egyptian aquaculture production by species category, 2007

In Tunisia, despite the substantial potential that has been identified (20 000 tonnes/year), aquaculture is not being developing as expected by the public authorities. Current production levels are about 3 400 tonnes, accounting for almost 3 percent of Tunisia's total fish production. Both marine and inland species are currently being farmed. Inland aquaculture produces an annual average of 500 tonnes of freshwater fish. In marine aquaculture, the European seabass and the gilthead seabream are produced.

In Algeria, aquaculture production, estimated at 405 tonnes in 2007, is essentially derived from inland fisheries. It consists mainly of freshwater species (common carp and Chinese carp) that have begun to find a market in areas where they are produced. In order to develop integrated aquaculture with agriculture in the Sahara, the authorities have experimented with broodstock and fingerlings of Nile tilapia, which has been very encouraging.

Aquaculture was initiated in the Libyan Arab Jamahiriya by culturing a variety of freshwater fish species. Owing to the limited resources of freshwater, dams and small lakes have been used for the semi-intensive culture of several species of carps imported from China (common, grass, bighead and silver carps) and catfish. Farming experiments have been successful, with good growth rates obtained for most species. Nile tilapia was introduced in the early 1990s. This species, well accepted on the local market, showed a rapid increase in production, utilizing water from agriculture irrigation channels. Mariculture began in the early 1990s with the development of the culture of the European seabass, gilthead seabream and mullet, raising the overall total production to 240 tonnes in 2007.

Syrian aquaculture is practised exclusively in freshwater. Specifically, it concerns warm freshwater fish culture. The main freshwater fish produced commercially are common carp and tilapias. The prevailing production systems are pond culture, cage culture and culture-based fishery in barrages. Aquaculture accounts for 47 percent of total fish production (8 425 tonnes out of a total of 17 881 tonnes in 2007), at an estimated value of USD24 million.

Total fish production

Since the mid-1990s, capture fisheries and aquaculture have supplied the subregion with more than 500 000 tonnes of fish per year (Figure 3.18). In 2007, the subregion's fisheries and aquaculture production reached 1 300 000 tonnes, with aquaculture accounting for 49 percent of this total. This is in line with the world trend, with aquaculture accounting for 47 percent (FAO, 2008) of food fish in 2006.

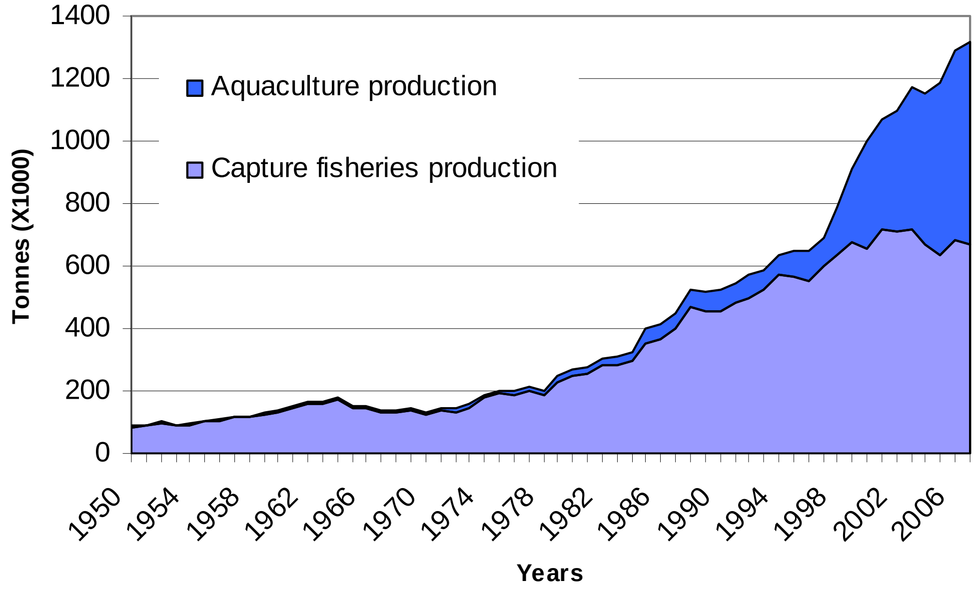

Figure 3.18 Total fish production for the southern and eastern Mediterranean subregion

Utilization and trade

Fish consumption

Fish and seafood consumption varies widely among the countries and remains relatively low by world standards (Figure 3.19). Egypt remains by far the largest consumer, and since the 1990s has accounted for more than 600 000 tonnes of fish and seafood production used for direct human consumption. An increase in demand could be met from higher aquaculture landings of fish. Factors contributing to increased consumption in some countries like Tunisia and Lebanon include economic expansion and development of tourism, while demographic expansion in Egypt, Algeria and the Libyan Arab Jamahiriya could explain the increase in consumption.

Table 3.3 Fish and fishery products apparent consumption, average 2003–2005

Country	**Production**	**Non-food uses**	**Imports**	**Exports**	**Food supply**	**Population**	**Per capita supply**
	(tonnes in live weight)					(thousands)	(kg/year)
Algeria	127 540	21	26 395	2 349	151 566	32 368	4.7
Egypt	876 733	188	253 262	5 996	1 123 851	71 556	15.7
Lebanon	4 648	9	27 017	246	31 410	3 965	7.9
Libyan Arab Jamahiriya	46 467	0	11 748	3 275	54 964	58 000	9.5
Syrian Arab Republic	16 773	0	26 763	128	43 407	18 392	2.4
Tunisia	106 064	3	36 153	18 935	123 280	9 996	12.3

The average per capita supply in the subregion is only 8.75 kg annually; the Syrian Arab Republic and Algeria rank lowest in this regard (Table 3.3). Egypt, which has the highest per capita food fish supply in the subregion, remains below the world average value, established since 2002 at about 16 kg/year (FAO, 2008).

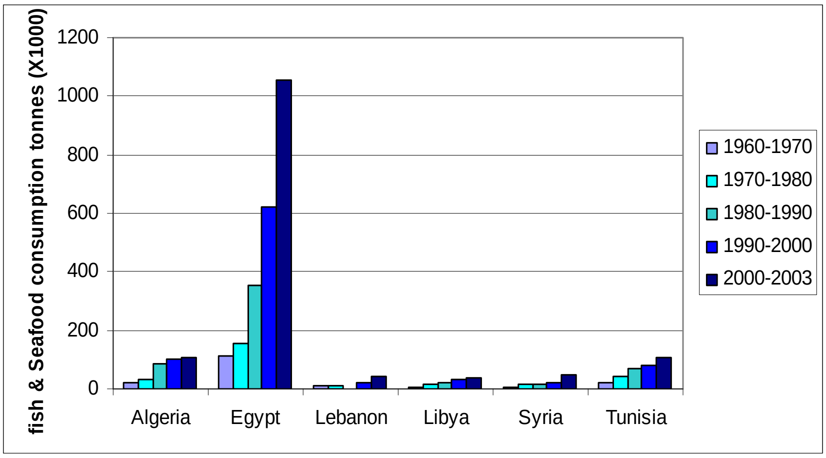

Figure 3.19 Average decennial fish and seafood consumption by country

Fish trade

In 2007, aquaculture and fisheries production in the subregion provided approximately 1 300 000 tonnes representing 44 percent of the total production by Mediterranean countries. Aquaculture produced more than 600 000 tonnes at an estimated value of USD1 239 million. The creation of wealth for the fisheries and aquaculture sector, and hence its contribution to national GDP, is difficult to ascertain. Where one has such information, this is generally close to 1 percent (e.g. Egypt, 1.7 percent; Tunisia, 1.2 percent).

In general, the subregion does not contribute substantially to international fish trade, although some countries, such as Tunisia, are major exporters of high-value fish, some cephalopods and crustaceans to European markets and Japan. The exports of fish and fishery products in the region reached USD185.6 million in 2006 (Figure 3.20), representing 0.2 percent of world exports. Tunisia alone accounted for 86.4 percent of the exports by the subregion.

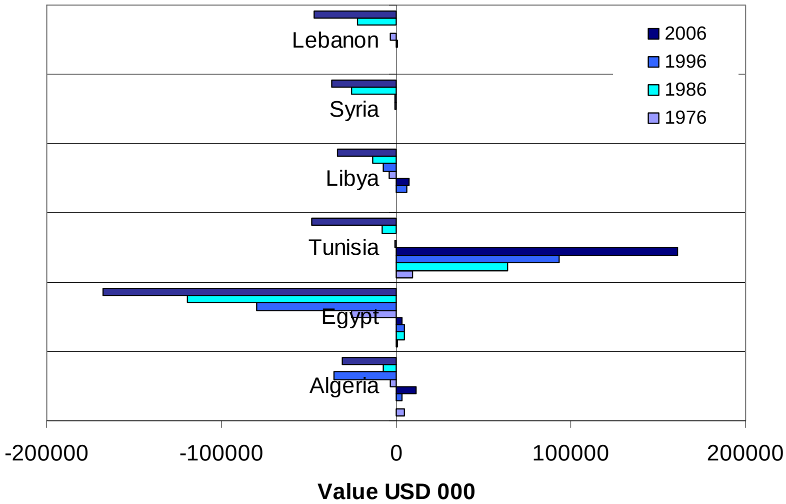

Figure 3.20 Fishery imports and exports, by country

Employment

Fisheries and aquaculture, directly or indirectly, play an essential role in the livelihoods of thousands of people in the region. In the period 2000–2005, an estimated 450 000 people were directly engaged, part-time or full time, in primary production of fish either in capture from the wild or in aquaculture. The contribution of fisheries to the workforce in the region could not be assessed. The data that are available revealed that the ratio of the number of fishers to the workforce is generally less than or equal to 1 percent, with an average of 0.9 percent in Member Countries of North Africa (e.g. Tunisia 1.05 percent).

Management

Ecosystem approach to fisheries

The fisheries and aquaculture sector provides significant incomes to the countries of the subregion in terms of food supply, employment opportunities and livelihood benefits for millions of people. In addition, the export of fisheries products represents an important source of foreign exchange earnings, contributing to national GDP. However, throughout this subregion, fisheries are threatened by overfishing, environmental degradation, anthropogenic ecosystem impacts in the form of species introductions, pollution and habitat fragmentation. There have been profound changes in land use of the coastal areas. Urban expansion is one of the most significant of such changes. In addition, the modernization and intensification of agriculture and the damming and modification of rivers flowing into the sea are having profound consequences for the system.

There is broad agreement at the international policy level that the EAF (FAO, 2003) is the appropriate and necessary framework for fisheries management, which flows from and is consistent with the Code (FAO, 2001). The EAF is defined as an approach that "strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries". It addresses both human and ecological well-being and merges two paradigms – that of protecting and conserving ecosystems and that of fisheries management, which focuses on providing food, income and livelihoods in a sustainable manner.

Most of the countries of the subregion have enacted management measures to control fishing, mainly aimed at protecting and conserving fisheries resources, including legislation, licensing of fishing vessels and regulating the characteristics and use of fishing gear. Some of them, e.g. Tunisia, are well advanced in identifying specially protected areas and/or adopting temporal closures to protect, in part, certain species during their reproductive period. An updating of the legislative frameworks is needed to improve the coherence among the countries and to reflect international agreements and instruments, including the Code (GFCM, 2005, 2007). It is also important that the legislation in these countries should incorporate implementation of the EA. It is a matter of concern that there is reported to be a low level, or even absence, of stakeholder involvement and consultation in fisheries management in these countries, and in the Mediterranean in general (CIHEAM, 2003).

The productive fisheries in the subregion are based on inland fisheries, particularly in Egypt. Indeed, inland fisheries management requires an EA, particularly in the catchment areas of large lakes and river systems, like the Nile River. The values and benefits of inland fisheries can be increased if such fisheries are protected through more effective governance and management. There are considerable opportunities to safeguard and enhance existing inland fisheries that can provide food security for millions of people, and to realize the potential for developing underexploited stocks. It is crucial to integrate these fisheries in natural resources management plans covering all stakeholders that affect the quality or quantity of the water resources throughout the catchment basin concerned.

Ecosystem approach to aquaculture

According to production trends, aquaculture will probably exceed fisheries turnover in the medium to long term. In a country like Egypt, inland fish production has steadily increased and today contributes significantly to national food security and limits the import of fish. In order to prosper, aquaculture will have to address some serious growth and cross-cutting issues related to its impact on the environment. The main issues facing subregional inland aquaculture development include competition for freshwater and suitable sites. The limited availability of freshwater (conflicts with agriculture and requirements for domestic water consumption) leads to increases in the stocking density in this form of fish rearing. In addition, there is a lack of intersectoral development planning, especially between

agriculture and aquaculture. Countries facing these constraints are turning to fish culture in existing inland waters and coastal marine waters to avoid the use of arable land.
Marine aquaculture is facing common problems in all the countries, such as a progressive saturation of available sites (both for extensive and intensive aquaculture), high competition in coastal areas (especially with tourism development), and market saturation and restrictions (particularly due to European Union import regulations).
The implementation of an EAA, defined as “a strategy for the integration of the activity within the wider ecosystem in such a way that it promotes sustainable development, equity, and resilience of interlinked social and ecological systems”, will permit the development of aquaculture, taking into account the full range of ecosystem functions and services, in the context of other sectors, policies, and goals, and improve human well-being and equity for all stakeholders.

Implementation of the EA in the subregion will require the development of institutions that can deliver such an approach, taking full account of the needs and impacts of other sectors.

Climate-change impacts

Climate change is a threat to the sustainability of capture fisheries and aquaculture development. Its impacts occur as a result of a gradual warming at the global scale and the associated physical and biological changes, as well as the consequences of the increased frequency of extreme weather events. Such changes will require adaptive measures in order to exploit opportunities and to minimize negative impacts on fisheries and aquaculture systems.

Impacts on water resources
One of the greatest potential impacts of climate change on human society is through its effect on water resources. The Mediterranean is already a region experiencing moderate to high water stresses, and climate change has the potential to exacerbate these stresses further. For the period 2031–2060, it is projected that runoff will decrease substantially in North Africa and the Near East (Arnell, 1999).

One measure of national water resource stress is the ratio of water used to water available, and countries using more than 20 percent of their total annual water supply are generally held to be exposed to water stress. Using this measure, all countries around the Mediterranean are expected to see an increase in water stress. The sole exception may be Egypt, where river runoff from the Nile River may actually increase owing to floods in the Central African Nile springs. Some countries have conducted studies to understand the impact of such changes on their countries. The Government of Algeria estimates that a 1 °C rise in mean annual temperature would lead to decreases in precipitation by 15 percent and in influx of surface waters by 30 percent. Subsequently, water demand would exceed available water resources by 800 million m^3 (Government of Algeria, 2001). The Government of Lebanon estimates that, by 2050, climate change could be responsible for nearly doubling the water shortage to 350 million m^3 of water (Khawli, 1999).

Impacts on sea-level rise
Model projections of regional sea-level patterns show very little agreement. For the Mediterranean, the values range from 1 to 2 cm of regional sea level rise per 1 cm of global sea-level rise (IPCC, 2001). This is because of the low tidal range in the Mediterranean combined with the limited potential for wetland migration. The Southern Mediterranean seems to be the most vulnerable region where flooding impacts can occur, particularly in deltaic countries (such as Egypt). Fisheries communities located in the deltas will be particularly vulnerable to sea-level rise and the associated risks of flooding, saline intrusion and coastal erosion.

Impacts on biodiversity
Climate change over the past 30 years has produced numerous shifts in the distributions and abundances of species. Increased temperatures will also affect fish physiological processes and the seasonality of particular biological processes, altering marine and freshwater food webs, with unpredictable consequences for fish production. This will result in both positive and negative effects

on fisheries and aquaculture systems in terms of production and marketing costs, and changes in the prices for fishery and aquaculture products. The impacts of climate change on the Mediterranean environment will relate particularly to marine biological diversity (animal and plant), via a displacement northwards and in altitude of certain species, extinction of less mobile or more climate-sensitive species, and emergence of new species. Fishing yields are expected to drop as a result of the accumulated conditions related to temperature, rainfall and the behaviour of animal and plant species.

The future impacts of climate change on fisheries and aquaculture are still poorly understood. The key to minimizing negative impacts and maximizing opportunities will be understanding and promoting the wide range of creative adaptive measures and their interactions with existing policy, legal and management frameworks.

Conclusions and recommendations

To diagnose the health of the resources in the Southern and Eastern Mediterranean subregion, there is a need to develop appropriate models to evaluate its potential and recommend management policies. Moreover, the lack of accurate data in the subregion, mainly in the eastern rim, has been a constraint to such approach. A special effort must be made to collect the data, to make them available to the researcher and management communities, and to improve the quality of these data in order to make any real progress in this area.

In the subregion, there is a potential for increased production from inland waters, which could be realized through improved management of existing stocks, utilization of unexploited stocks and increased exploitation of reservoirs. Expansion of culture-based fisheries and aquaculture provides a vast potential for growth in production. To realize this potential, there is a need to improve the information base for management, infrastructure, support services and training as well as prevent environmental degradation.

The subregion appears as the most threatened area in the world by climatic change. To minimize the negative impacts of such change on fisheries and aquaculture systems, adaptive measures are required although the countries have limited level of services, technological and economical resources, which are likely to result in very restricted adaptation capabilities to environmental and climate changes. The adaptive capacities of fisheries and aquaculture production systems could be increased by applying existing good governance and management principles and approaches. Such approaches include the EAF and the EAA, which involve practices of adaptive and precautionary management based on appropriate social, economic, political and institutional incentives.

A common understanding of the EAF and EAA concepts is developing, and an effort is now being made to incorporate the principles of the EAF and EAA in policies at the national level. However, there is still much to do to make these principles operational in the practical management of fisheries. In particular, they have to be socially acceptable and based on strengthened institutions at the local and national levels.

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3.3 The ecosystem-based approach to fisheries and aquaculture for the Red Sea and Gulf of Aden

Introduction

The RESGA subregion has always been a vital maritime trade route linking the Near East with the other continents of the Old World. Over the course of the past few decades, the oil industry and marine transportation of oil has increased in significance in the subregion, placing it frequently at the centre of the geopolitical strategies of industrialized countries. At the same time, an increasing interest in the subregion's living marine resources and their habitats has developed both at local and international levels. Early studies on the subregion's living marine resources can be dated back to the collections of flora and fauna, particularly fish, made by the Swedish naturalist Peter Forsskal in 1761–62. Most recently, projects funded by the GEF and other donors aim to help in the conservation and sustainable management of the biodiversity of the subregion.

The Red Sea is a long narrow basin approximately 2 000 km long, with an average breadth of 280 km. Being a semi-enclosed body of water, it is characterized by high water temperatures and high salinity. There are no major river inflows, and the water lost through evaporation far exceeds precipitation. The loss of water through evaporation is replenished through the inflow from the Gulf of Aden through the Strait of Bab-al-Mandab. Primary productivity is relatively low owing to poor surface circulation in the absence of strong wind systems. Productivity is greatest in the south, where it is stimulated by the inflow of nutrient-rich Indian Ocean water. The north of the Red Sea is divided into the Gulf of Suez, a shallow sea less than 100 m deep, and the Gulf of Aqaba, a deep rift basin reaching 1 800 metres in depth. The two gulfs are similar in size and shape. The geographical separation of the Red Sea from the Gulf of Aden is via a 100 m-deep sill about 125 km north of Bab-al-Mandab.

The RESGA subregion is surrounded by seven countries, each with different historical and cultural backgrounds (Figure 3.21). However, owing to the relatively recent need for resource sharing recognized at the global level, the surrounding countries have initiated a form of unity under the umbrella of the Arab League known as the PERSGA. The goals and agenda of this organization, generated during the Jeddah Convention (1982), concentrate on the sustainable use of the available living marine resources in the area. However, the lack of fundamental basic information about the existing marine resources, differences in the degree of development between those countries, and the lack of intergovernmental coordination have been the main setbacks facing the achievement of the goals.

The PERSGA, in close collaboration with relevant regional and international organizations, began implementing activities and programmes to deal with the various threats facing the coastal and marine environments in the subregion. The most significant threats included: environmental degradation, non-sustainable use of living marine resources, maritime traffic, oil production and transport, urban and industrial development, and the rapid expansion of coastal tourism (PERSGA, 2001).

The Red Sea is globally renowned for its unique and attractive marine and coastal habitats with high species diversity. For example, the coral community within the RESGA is composed of more than 250 species of stony corals. This is the highest diversity in any part of the Indian Ocean (Pilcher and Alsuhaibany, 2000). Of these, 6 percent are believed to be endemic (Sheppard and Sheppard, 1991). These habitats are under variable anthropogenic pressures, especially adjacent to urban and industrial areas, port facilities, major shipping lanes and in the vicinity of coastal tourist developments (PERSGA, 1998). The widespread destruction of coastal and marine habitats is a major transboundary concern in the subregion, with impacts of habitat and community modification considered severe for the Red Sea's living marine resources (PERSGA, 1998).

The Red Sea has a number of unique marine habitats, including seagrass beds, saltpans, mangroves, salt-marshes and the unique coral reefs. The Gulf of Aden is a region of oceanic upwelling, resulting in high productivity of fish resources, particularly in the eastern part of the Gulf. The fisheries of the RESGA are of considerable socio-economic importance to the member States of the PERSGA, in terms of national food security and income generation for rural communities. Fisheries resources are exploited by artisanal subsistence fishers, local commercial fisheries and foreign industrial fisheries targeting invertebrates, demersal finfish and pelagic finfish. Many species cross national boundaries and are essentially shared stocks.

The objective of the present work is to present an overview of the current status of fisheries in the subregion and to analyse the possibility of applying the concept of responsible fisheries in the area through addressing practically all the ecosystem considerations and to identify the possible impact of climatic change on the sustainability of fisheries in the area.

Map of the Red Sea and Gulf of Aden Region and its surrounding countries.

Figure 3.21 Map of the Red Sea and Gulf of Aden subregion

Status of fisheries in the subregion

Fishing in the RESGA subregion is dominated by small-scale, artisanal activities. As is the case throughout the world, such fisheries are by their nature notoriously difficult to monitor, owing to the large number of small craft and fishermen, and the wide range of landing sites used. Reliable data are therefore often very difficult to obtain on a national basis, and comparisons of equivalent data between countries are difficult to undertake with precision. One of the problems facing national administrations in the subregion in trying to collect accurate data on artisanal fisheries is the mobility of the fleet, with a large number of boats moving to different areas at different times depending on the weather, availability of fish and market outlets. The present section summarizes the available information about the status of fisheries in the subregion with special emphasis on some countries that have more transparency and availability in their information sources.

The fisheries of the RESGA are of considerable socio-economic importance in terms of national food security and income generation for rural communities, with the exception of Jordan, which has minimal fisheries in the Red Sea. Fisheries resources are exploited by artisanal subsistence fishermen, local commercial fisheries and foreign industrial fisheries targeting invertebrates, demersal finfish and pelagic finfish. Many species cross national boundaries and are essentially shared stocks.

According to the published data from the area, the subregional artisanal fleet operating in the RESGA area comprises at least 54 500 fishermen and about 15 500 vessels of different types ranging from the smallest (*hori*) to the large fishing boats (*balanse*). Most vessels are locally made of wood, 6–7 m in length with petrol outboard motors of 8–20 hp. A fleet of larger artisanal vessels of 10–15 m operate with 50–150 hp inboard diesel engines. Artisanal fishermen use a range of gear, including longlines, handlines, gillnets, trawls, trammel nets, tangle nets, set nets, traps and spears. Figure 3.22 presents the artisanal profile of the subregion.

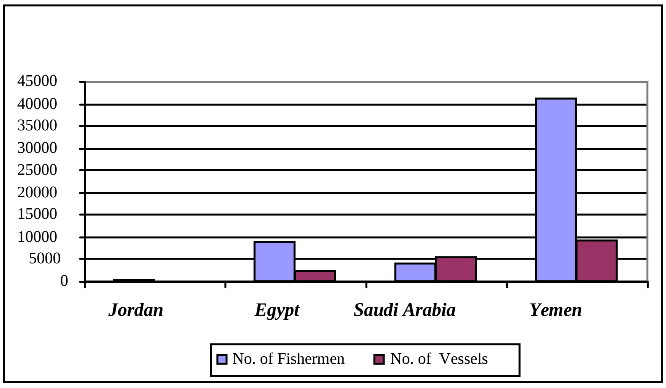

Figure 3.22 Artisanal fisheries profile of the RESGA subregion
Source: PERSGA, 2006.

According to the data collected from the subregion the industrial fleet consists of about 12 057 fishermen and 1 600 industrial vessels. Industrial vessels utilize purse seine, trawl, longline and vertical dropline gear. Figure 3.23 represents the industrial profile of the subregion. Owing to the nature of the Red Sea, the industrial fishery vessels have a rather limited chance in the north except for the Gulf of Suez, while the vessels of Saudi Arabia and Yemen prefer to operate in the southern waters and even extend their range to reach the Indian Ocean. In the Gulf of Aden, large industrial fisheries using "distant water" factory trawlers based in the area exploited demersal and small pelagic fish resources in the past, but because of lack of profitability have not functioned for some time. The situation in Somalia remains uncertain with informal reports of fishing companies undertaking operations and also substantial illegal fishing, particularly outside of the Gulf of Aden by foreign operators.

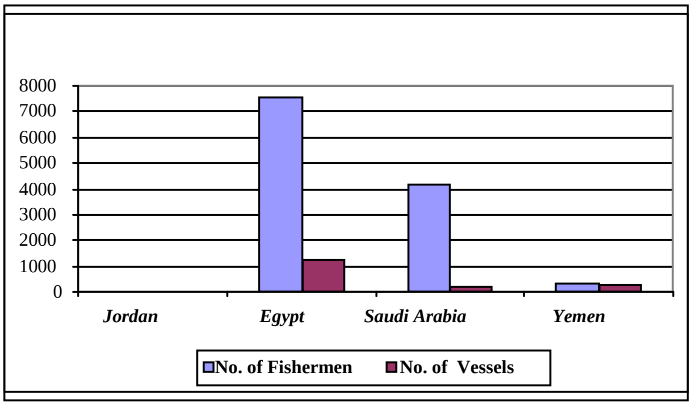

Figure 3.23 Industrial fisheries profile of the RESGA subregion
Source: PERSGA, 2006.

The four countries included in this review (Egypt, Jordan, Saudi Arabia and Yemen) represent about 96 percent of the subregional sector production. According to the available information about these countries, the artisanal and industrial fisheries produced about 30 269 tonnes of invertebrate species and 261 842 tonnes of finfishes in 2007. These figures indicate a considerable increase in the subregion's production from 236 094 tonnes to 297 058 tonnes in the period from 1998 to 2007 (Figure 3.24). Yemen accounted for 56 percent of total production of invertebrates, Saudi Arabia 22.7 percent, while Egypt accounted for only 5.7 percent. Important commercial invertebrate species include penaeid shrimps in the Red Sea and cuttlefish and rock lobsters in the Gulf of Aden.

In 2007, Yemen accounted for 58.5 percent of the subregion's finfish production, followed by Saudi Arabia at 24.1 percent, then Egypt by 17.3 percent, while Jordan represented only 0.05 percent of the subregional total. Pelagic finfish catches are dominated by sardine, Indian mackerel, Spanish mackerel and yellowfin tuna. The demersal catch is dominated by species of snapper, jack, emperor, lizardfish, grouper, seerfish, rabbitfish and seabream.

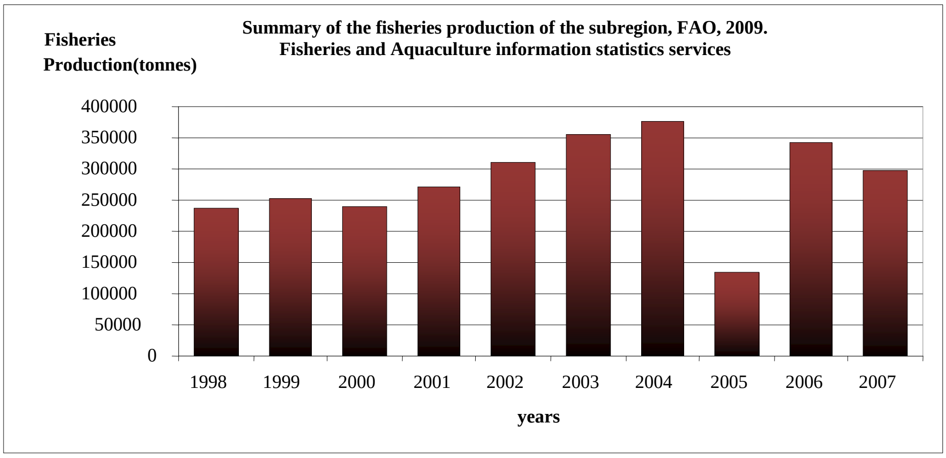

Figure 3.24 Summary of fisheries production in the RESGA subregion
Source: FAO, 2009.

Reported catches from the RESGA area continued their steady increase during the period from 1950 to 2005 reaching a relatively high rate of increase in the last ten-year period. The comparison of data collected from different sources showed that some of this may be from improved reporting practices, but irrespective of the cause, this is a relatively substantial increase when compared with other FAO statistical areas. Applied fisheries research and stock assessment throughout the subregion have been neglected in the past two decades. In most countries, no stock assessment has been undertaken since the cessation of collaborative research programmes conducted in the 1970s and 1980s. Consequently, most national authorities do not have reliable recent resource information regarding stock status, population parameters, estimates of potential biological yield or comprehensive and reliable catch and effort statistics even for the commercially important stocks. Such information is required in order to develop rational management plans, monitor the effectiveness of management strategies and assess the socio-economic value of the fisheries.

A more realistic evaluation of the fisheries of the PERSGA region, conducted by Tesfamichael and Pitcher (2006) using multidimensional scaling, showed that all countries have similar values ethically and economically, and in the technological field all countries have similar values except Egypt, which has lower sustainability. The main differences are in the ecological and social fields. Eritrea and the Sudan have the best scores ecologically. In the social field, Egypt has the best score, then Yemen followed by the Sudan, Eritrea and Saudi Arabia. The west and east coasts of the Red Sea scored the same in all fields except for ecology, where west coast fisheries scored better than those of the east coast. The economic sustainability evaluation of industrial and artisanal fisheries is similar, but the artisanal sector does better in ecological, technological and ethical fields. Surprisingly, the industrial sector rated higher in the social evaluation.

The difference between countries is not as obvious as it is between artisanal and industrial. In fact, the fishing operations of the artisanal fisheries, in terms of boats, facilities, gear and fish storage, are similar in all Red Sea countries. However, there are differences in other aspects. For example, per capita fish consumption is highest in Yemen, followed by Egypt, while the lowest per capita consumption is in Eritrea and the Sudan. It was predicted that Eritrea and the Sudan would be the countries to benefit most from expanding the fishing industry in the Red Sea. However, these countries seem to utilize their resources least and they also have the highest ecological sustainability status. This is reflected also in the comparison between the west (Egypt, Sudan and Eritrea) and east (Saudi Arabia and Yemen) Red Sea fisheries, and there are some reports that other Red Sea countries fish in Sudan and/or Eritrea legally or illegally. Sheppard (2000) stated that, due to lack of efficiency and proper market structure, Red Sea fisheries have been sustainable, with some exceptions such as the Egyptian shrimp fishery in the Gulf of Suez.

The marine aquaculture in the area is mainly limited to Saudi Arabia and Egypt. In Saudi Arabia, aquaculture production, although still small in comparison with wild capture fisheries, is growing rapidly, with production doubling from 2 960 tonnes in 1996 to 5 600 tonnes in 2000, with a further increase to 8 018 tonnes in 2001. This represents about 14 percent of fish production in the country. There were 149 farms in operation with the majority of production coming from freshwater aquaculture, primarily tilapia species. However, marine aquaculture is expanding rapidly, particularly shrimp farms on the Red Sea coast in the region of Jizan and the Tihama Plains. Other marine species in commercial or pilot-scale production include grouper (*Epinephelus coioides*), seabream (*Sparus auratus*), rabbitfish (*Siganus caniculatus*) and mullet (*Mugilidae* spp.). There is also interest, at a feasibility level, in the culture of lobster, molluscs, seaweed and ornamental fish. In Egypt, projects concerning marine aquaculture on the Red Sea coast have not been successful and most of the land allocated for them is still not developed. The reason for this is that the funds allocated by banks for such projects is negligible.

The economic contribution of the fisheries sector to the national economy differs from one country to another. In Jordan, the commercial fisheries sector is small and contributes less than 0.01 percent of GDP. Aquaculture production from intensive farms is increasingly important from a socio-economic point of view in rural areas, particularly in some areas of the Jordan Valley. In comparison with the oil industry, the contribution of the fishing industry to Saudi Arabia's economy is very small. While Saudi citizens own and operate traditional and industrial vessels, the sector is heavily dependent on immigrant workers, with more than 50 percent of these workers coming from Bangladesh and India. In addition to commercial food production, fishery resources also support a significant recreational fishing industry, particularly on the Red Sea coast. The fishing industry has a relatively minor direct role in the economy of Egypt, but nevertheless, domestic fish production makes a valuable contribution to the national food supply and to the traditional way of life, in which fish consumption plays an important part. In addition, it is a significant source of food for the tourist industry. In some cases, fishermen (especially in the Red Sea) sell their catch directly to restaurants or hotels. The fishing industry is also important for the livelihoods of more than 65 000 fishermen and other people employed full time in related activities. The fisheries sector is considered to be third in order of importance in Yemen's economy.

The value of the biological resources, including fisheries, to the prosperity of the subregion, particularly among the coastal populations, has long been recognized. The contribution of fisheries to GDP is relatively small (less than 1 percent), except in Yemen, where this sector accounts for 15 percent of GDP (FAO, 2005). Nevertheless, fisheries, particularly artisanal fisheries, provide food and employment for thousands of the subregion's inhabitants. For example, in Yemen, more than 220 000 people depend on fishing as their principal source of income. The fish resources of the Red Sea are regarded as an important source of domestic protein for coastal communities. Marine fisheries have potential for further development, for example, in Djibouti, where the potential contribution to GDP could rise substantially from 0.1 percent to approximately 5 percent (FAO, 2005). However, realization of that potential will depend on the continued upgrading of infrastructure and development of export markets.

Implementation of the ecosystem approach in the subregion

Despite the fact that the EAF is internationally recognized as a management tool, the implementation of such a principle in the RESGA subregion could be impossible in view of the many anthropogenic and traditional habits that control the behaviour of the fisheries community in this area. The main reason for this is the lack of coordination and trust between the authorities and the fisheries community. The great bulk of the fishers in this area prefer to work alone on a day-to-day basis and not to be connected to any organization or controlling system. Such behaviour contributes greatly to the lack of accurate information about the fisheries in most of these countries. Even those who assert that they have accurate data about their catch cannot provide evidence of their accuracy.

Many attempts have been made by the governments to reach the fisheries community. The most successful one was through the establishment of a NGO at several landing sites or in cities that have an aggregation of fishers. Such organizations contribute greatly to the community; however, being controlled by the fishers themselves, they did not reach the fully mature stage required to understand the importance of the ecosystem to their working future.

In most of the subregion, the real contribution to the current approach is coming from the environmental protection and nature conservation authorities. However, the principle of "rules are meant to be broken" is still applied in many areas where fishing in restricted areas is the favourite task for many fishers. This is clear in the tendency of the fishers of some countries to fish in closed areas or when the fishing season is closed.
It seems that the development of managerial skills in the area will play a very effective role in the implementation of an EAF. The messages delivered to the fisheries communities within the subregion must convince them that the application of ecosystem-based fishery management is likely to:

- contribute to increased abundance of those species that have been overfished;
- contribute to the stability of employment and economic activity in the fishing industry;
- help in the protection of marine biodiversity on which fisheries depend;
- help in deciding the limits of the sea to provide resources and the ability to stay within those limits, in addition to defining the acceptable levels of change in marine environments due to fishing.

The variations in the degree of fisheries management in the region may conflict with the application of the ecosystem-based principle. However, awareness raising regarding the importance of how different ecosystems affect the structure and abundance of fisheries could be considered as the first step towards implementing such an approach.

The efforts contributed by the regional organization (PERSGA) in the fields of habitat and biodiversity as well as living marine resources must be invested in this direction. The recognition of the importance of the present ecosystems in the RESGA area from the fisheries point of view must be explained in a more simple and understandable way. Instead of concentrating on the conservation of the marine ecosystem from the point of view of the ecological authorities, it is necessary to obtain the support of the fisheries community as well. In this way, those accused of destroying the ecosystems will become partners in the process of sustainability in usage.

Despite the fact that the EBFM approach is not applicable in the current situation across the subregion, the possibility of applying this approach in the area in the future would increase if the planning for it were considered by the different authorities within each of the neighbouring countries and conducted under the umbrella of the regional organization. The suggested plan to apply the principle and reach the goals of EBFM should first support the movement of recognizing the distribution of ecosystems within the area and their contribution to the fisheries within the subregion.

Accordingly, it is suggested that the problems must initially be addressed at the country level, where authorities can consider the benefits gained by the multiple users of the ecosystem. This will open the door to a wide range of objectives, frequently ignored in the past, and must be considered in the process of selecting optimal fisheries management measures and strategies. Normally, dealing with such inevitable subjects generates a large number of conflicts between different stakeholder groups. These need to be reconciled and resolved if management is to be successful and the overall societal goals achieved. These conflicts are normally solved through meetings at ministerial level and result in new laws or regulations defining the boundaries and duties of each of the stakeholders. Once the conflicts within the country have been solved, the main concept of EBFM can be introduced at a higher level (e.g. the regional level) through the regional organization (PERSGA), that has already included the sustainable use of living marine resources in its agenda.

The impact of fisheries on ecosystems in the subregion

The impact of the fisheries on the ecosystems in the area is poorly documented in most countries. However, fishing usually affects other components in the ecosystem in which it occurs. For example, there is often bycatch of non-targeted species, physical damage to habitats, food-chain effects and other factors, and in recent years there has been a growing realization of the impact of fisheries on the different marine ecosystems (FAO, 2003).

Coral reef, seagrass and mangroves are the main ecosystems found on the coast of the RESGA countries. Despite the fact that most of these ecosystems have some form of protection or are located within protected areas in these countries, many illegal fishing practices persist in these areas. The impact of such fishing practices are summarized in the following points:

- the reduced abundance of individual species within coral reef ecosystems, for example the case of losing large predators (groupers) as a result of selective fishing or removal of target species, which negatively affects other species that depend on it as prey;
- destruction of a certain habitat type (damage to corals by anchoring) that exposes the prey to the predator as a result of losing shelter;
- the use of unsustainable fishing techniques resulting in deterioration in the recruitment of certain species and reduction of the possibility to restock or recover;
- catching of non-target species as bycatch and their disposal;
- the extent of competition between fisheries and species of concern such as marine mammals, turtles, seabirds and sharks. This includes consideration of both “direct competition”, which involves reduction (by consumption or utilization) of a limited resource but with no direct interactions between the competing species, and “indirect competition” in which the competitors may target different resources but are linked because of a food-web effect;
- the reduction of biodiversity owing to targeting groups of species to the maximum limit, especially on offshore reefs or reefs around islands, which results in changes in the community structure;
- altering the trophic levels in the ecosystem by removing certain trophic categories, resulting in the evolution of a mono-specific type ecosystem;
- the effects of habitat modification. This includes consideration of effects such as trawling, damaging benthic habitats, perhaps having an indirect negative effect on fish stocks;
- changes in the ecosystem state (e.g. mangrove cutting, collection of corals and marine animals) that result in a less productive/desirable state of the ecosystem;
- indirect impacts resulting from the use of old and corroded fishing boats spilling fuel and oils into the marine environment.

Suggested steps towards the implementation of the EAF in the RESGA subregion

Like most of the successful plans implemented in the RESGA area, the EAF must be carried out in steps and according to a regionally studied action plan. The suggested action plan should include the following components.

Environmental inventory
This includes an assessment of the present living marine resources in the coastal area at a country level using standard and internationally recognized methods of assessment. The collected data should be verified and as accurate as possible. Such data can be easily obtained in certain countries; however, in others, the personnel needed for data collection may need training. The regional organization should take responsibility for training in the standard methods of collecting data in those countries.

Environmental assessment
This concerns assessing and evaluating the sources and causes of environmental problems as well as their magnitude and impact on the marine environment. Emphasis is placed on:
levels and effects of marine pollutants;
studies of coastal and marine activities and their socio-economic effects;
environmental degradation.

Environmental assessment is undertaken to assist national policy-makers in managing their natural resources in a more effective and sustainable manner, and to provide information on the effectiveness of legal and administrative measures taken to improve the quality of the environment.

Environmental management
The regional programme includes a wide range of activities in the field of environmental management. Such activities are:

- the subregional integrated coastal zone management plans;
- marine pollution contingency plans;
- establishment and management of specially protected areas;
- raising the capacity of national institutions and experts to participate fully in the programmes.

However, the results of carrying the environmental assessment should indicate the needs for special environmental management actions. These actions need to be addressed on both the national and regional levels. One of the most relevant programmes is the sustainable management of living marine resources in the RESGA region.

Improve environmental legislation
It is well known in the countries of this area that implementation of any programme needs to be supported by law. So, the preparation for the new management scheme for the living marine resources in countries in the area should be accompanied by a set of legislation that creates harmony in the relations between the countries in this field. Some of the countries (Egypt, Saudi Arabia, etc.) have their own environmental laws; however, they are concentrated on the protection of the environment not the sustainable use of it. On the other hand, the management of the fisheries sector belongs to a different part of the administration – causing a great deal of conflict between parties within the same government.

Institutional arrangements
The main role of the regional organization when adopting the action plan comes from its power to bring the governments to agree to let the organization act as the permanent secretariat of the action plan and to agree on the mechanisms to be used for the periodic review of the progress of the agreed workplan and for approving new activities and the necessary budgetary support.

Financial arrangements
In addition to its previous institutional role, the regional organization must:

- ensure governments' contributions towards the costs associated with the implementation of the action plans;
- work towards generating enough funds from international donor organizations to finance the plans;
- control the flow of funds and ensure that they are channelled through specially established trust funds to which the governments participating in the action plan make annual contributions.

Understanding of possible climate-change impacts in the subregion

The IPCC (2007) projects that atmospheric temperatures will rise by 1.8–4.0 °C globally by 2100. This warming will be accompanied by rising sea temperatures, changing sea levels, increasing ocean acidification, altered rainfall patterns and river flows, and higher incidence of extreme weather events. The productivity, distribution and seasonality of fisheries, and the quality and availability of the habitats that support them, are sensitive to these climate-change effects. In addition, many fishery-dependent communities and aquaculture operations are in regions highly exposed to climate change (Allison *et al*., 2009).

It is well documented that the Red Sea has the highest temperatures and salinities observed in the world's oceans. The extremely high evaporation rate leads to formation of salinity fronts, on which temperature fronts tend to develop. Although these fronts are poorly studied *in situ*, satellite observations hold promise given the largely cloud-free conditions over the Red Sea (Belkin, Cornillon and Sherman, 2008). The only known events where the Red Sea surface water temperature has exceeded 28.5 °C occurred in 1969 and again after the strongest El Niño of the last 50 years in 1998–99.

Developing policies and strategies to address climate change impacts on fisheries and aquaculture depends on identifying vulnerable places and people and understanding what drives their vulnerability. This requires vulnerability assessments at multiple scales and taking into account multiple interacting drivers. This could be achieved through intensive study of:

- the exposure of a particular system to climate change;
- the degree of sensitivity to climate impacts;
- the adaptive capacity of the group or society experiencing these impacts.

Improved management of fisheries and of marine ecosystems can undoubtedly play an important role in adapting to the impacts of climate change. Most of the improvements that are needed do not require new science or understanding; they require patient development of acceptable, effective, responsive social institutions and instruments for achieving adaptive management.

In the RESGA subregion, climate change is an additional pressure on top of the many (fishing pressure, loss of habitat, pollution, disturbance, etc.) that the marine environment already experiences. This means that the impact of climate change must be evaluated in the context of other anthropogenic pressures, which often have a much greater and more immediate effect. Conversely, it is evident that fish stocks will be more resilient to climate impacts if the stresses relating to other factors, such as overfishing and pollution, are minimized (Brander, 2005).

Although our knowledge of the processes by which climatic and environmental factors affect fish at individual, population and ecosystem level remains far from complete, we are already able to observe changes at all these levels – changes that can be confidently ascribed to climate change. Globally recognized changes in distribution of fish and plankton are particularly striking because they are more rapid than the changes occurring in terrestrial fauna and flora (Francis, 1990). In addition, some very basic biological research on the physiological and population constraints for individual species would help in defining biogeographic boundaries and, hence, in making projections of future distribution shifts (Sharp, 2003).

The lack of evidence of the relationship between climate changes and fisheries landings in the RESGA area is due to the following reasons:

- lack of accurate data or records about the landings;
- the tendency to provide information showing increasing fisheries production as a sign of successful fisheries management by governments;
- the use of different and misleading systems in recording the data;
- the presence of too many anthropogenic activities that can be accused of or blamed for stock depletion;
- the lack of transparency and coordination at regional level;
- the common belief that global warming is a God-intended action or that it is a part of natural cycle.

Much of the research conducted in the area on the local and national levels has not recognized anthropogenic climate change as a possible effect on fish production. However, a closer look at the available data suggests that there is a link between fish production and climate – this points out the need to include the effects of global warming as a possible impact in the near future. The revising of the scientific data and results reported in the area (Head, 1987; Sanders and Morgan, 1989; Hariri *et al*., 2000; Tesfamichael and Pitcher, 2006) suggests that shifts in climate could have noticeable effects on some, if not most, major commercial fish stocks in the area.

The main indicators of the climate changes impacts that should be taken into consideration at both national and regional levels include:

- Changes in production: This includes the natural increase or decrease in the production of the region without any interference from other factors (e.g. increase in number of fishing boats, fishermen).
- Changes in fish population processes: This could be monitored on the small scale (local or national) where impacts of climate change on biological production are ultimately the sum of processes that act on individual organisms. The processes, whose response to environmental variability can be studied in exquisite detail, are growth, reproduction, mortality and behaviour.
- Changes in the environmental factors: This includes monitoring of the environmental factors that could affect the biology of the fish, such as changes in the physical-chemical properties of the sea water (pH, temperature, salinity, etc.).
- Decline in total biomass of fish: This can be good evidence if preceded by a decline in mean weight-at-age. Decline in growth rate provides valuable advance warning of reduced surplus production, which can result in a decline in stock biomass.

The questions that need to be answered concerning this region of the world are:

i. Are we really going to be affected by global warming?
ii. Is it too late to react?
iii. What policy processes nationally and regionally do fishery and aquaculture agencies need to engage with to finance and implement adaptation?
iv. How can climate-change adaptation and management be effectively incorporated into fishery and aquaculture development and management planning?

Conclusions

Several issues in the fisheries sector need to be dealt with before the implementation of an EAF/EAA in this subregion; among which:

- The absence of effective controls, surveillance and regulation enforcement in most of the countries has resulted in widespread poaching and habitat destruction by foreign and national vessels.
- The legal framework provided for fisheries management and development is weak in many states. Penalties for infringements are too low to act as an effective deterrent and encourage compliance by fishermen.
- Enforcement is virtually non-existent in most of the subregion. However, some states are acting to strengthen the national legal framework through higher penalties, provisions for habitat/biodiversity conservation and clearly defined powers for management authorities and enforcement officers.
- In all the RESGA countries, national institutional structures lack the administrative and technical capacity to formulate and implement realistic and effective fisheries management policies and strategies.
- A generic problem throughout the subregion is the lack of financial and material resources allocated to those authorities responsible for fisheries research, management and development.

Recommendations

- To ensure the future of the fisheries sector in the RESGA area, it is suggested that all governments in the subregion aim to develop a clear policy for national fisheries within a framework for integrated coastal management.
- Greater harmonization of national legislative frameworks for fisheries and the environment, data collection, research and multisectoral studies, operations and procedures would provide a better basis for cost-effective management.
- The concept of integrated management and coordination between ministries (currently non-existent in most countries owing to the strong sectoral nature of government) must be encouraged.
- Institutional capacity needs to be strengthened in the areas of regulatory policy, fisheries management and environmental conservation.
- Although aquaculture has been seen as a major alternative source of fresh fish supply and is growing rapidly, production from this sector has not grown fast enough to meet increased demand.

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3.4 Adapting to climate change: a review of the ecosystem approach to fisheries and aquaculture in the RECOFI region

Introduction

The RECOFI is a regional fisheries body located in the Near East and covers an area of water including the Persian Gulf, Gulf of Oman and north Arabian Sea. There are eight countries with coastal waters in RECOFI, including Bahrain, Iran (Islamic Republic of), Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (Figure 3.25).

The climate of the RECOFI region is of subtropical nature. Salinity is high compared with neighbouring marine environments, particularly in the Persian Gulf. Freshwater input into the Persian Gulf is low and solely from the Arwand River, which collects water from the Karoun, Euphrates and Tigris Rivers. The Gulf of Oman and north Arabian Sea receive water from the Indian Ocean and the Indus River.

Climate change is a phenomenon that cannot be disregarded. The average world temperature has risen, glaciers are melting, and natural disasters are increasing. Ocean acidification is evident. Drought is occurring in the region.

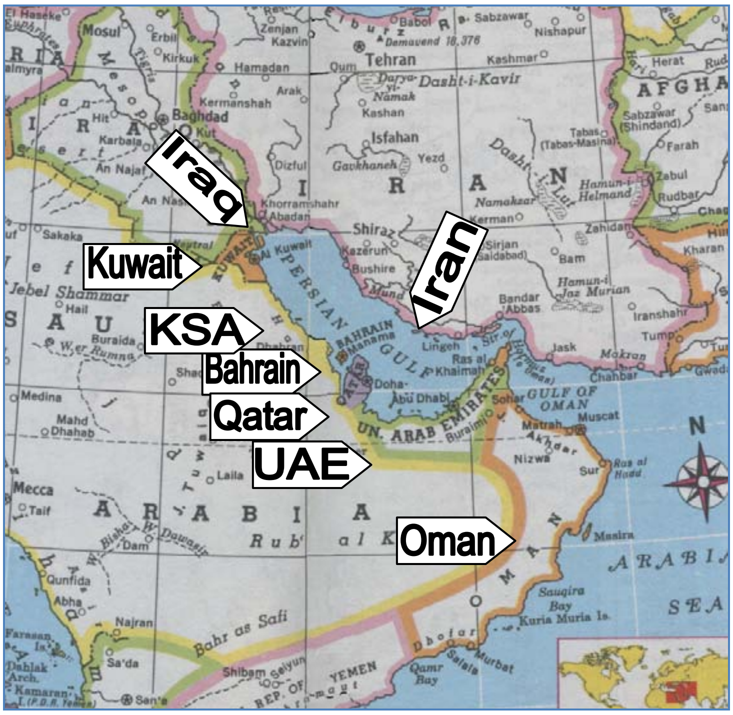

Figure 3.25 Map of the RECOFI region
Source: Hammond, 1978.

Member country fisheries and aquaculture profiles

Bahrain
Bahrain is a flat country with an area of 706 km^2 and 32 islands in the Persian Gulf. There are very few freshwater resources, and so fishing and aquaculture are mainly limited to marine waters. This country used to cover 695 km^2 in 1991, but by land reclamation and dredging, which resulted in some environmental and coral destruction, it has been able to increase its area to 706 km^2. Bahrain's population is 963 000.

In 2001, fish production in Bahrain was 11 230 tonnes, imports were 4 080 tonnes, and fish exports were 5 990 tonnes. Fish imports in 2003 were 3 358 tonnes for a value of USD6 880 000, while exports in the same year were 7 202 tonnes, valued at USD11 595 000. Crab, finfish and shrimp are mainly exported to Saudi Arabia. Bahrain has 590 km of coastline and a fishing industry that catches mainly shrimp, crab, finfish (mostly rabbitfish, emperors and groupers). There are approximately 2 300 fishing boats, 85 percent of which are made of fibreglass, and 15 percent of wood. The main types of fishing gear are shrimp trawl, gillnet, wire trap (gargoor), and hook-and-line. Shallow-fixed stake nets (haddrah) are mainly banned, as are drift nets but they are still widely used, despite enforcement measures taken by Bahraini authorities.

Although fisheries in Bahrain are not economically important, in the sense that they comprise only 0.4 percent of GDP, they are of socio-economic importance as a result of their role as a main source of employment for many rural areas.

Fisheries in Bahrain are mainly artisanal and are increasing in importance. Fishing increased dramatically in 1996, and has continued to increase since; however, the composition of fish products of Bahrain has changed with a decrease in the shrimp and red grouper (hamour) catches and increases in the crab and finfish catches. It is suggested that some popular species are overexploited.

It is estimated that 7 200 people are directly employed in the fisheries sector in Bahrain, with an additional 2 000 persons indirectly employed. In 2003, fish consumption per capita was 16.7 kg in Bahrain. In 1993, work started on aquaculture, focusing on grouper (*Epinephelus coioides*), rabbitfish (*Siganus canaliculatus*), and yellowfin seabream (*Acanthopagrus latus*). Later, in 1999, culture of sobaity bream (*Sparidentex hasta*) was successfully implemented. Bahraini hatcheries supply fry for local and regional aquaculture (FAO, 2009).

Iran (Islamic Republic of)

The Islamic Republic of Iran is a mountainous country of 1 648 195 km^2 located to the north of the Persian Gulf. More than half of the country is covered with mountains, one-quarter is desert and the rest is agricultural land. Most rivers are small or of medium size, while the Karoun River is the only navigable large river in the Islamic Republic of Iran. There are four main watersheds, which empty into the Caspian Sea, the north RECOFI area (Persian Gulf and Gulf of Oman), Lake Urmia, and central inland lakes.

There are approximately 170 000 persons working in fisheries and aquaculture in the Islamic Republic of Iran. Some 28 000 aquaculturists raise Chinese carp, rainbow trout, and shrimp in the Islamic Republic of Iran. Approximately 13 000 people fish on Caspian Sea coasts, mainly on bony fishes, sturgeons and kilka. The remaining 130 000 people fish in the Persian Gulf and the Gulf of Oman, mainly for tuna, shrimp, demersal and pelagic fish species. The Islamic Republic of Iran has 2 700 km of coastline, 1 800 km of which is located within the area covered by the RECOFI. Fish production of the Islamic Republic of Iran in the RECOFI area was 329 000 tonnes in 2007. Fish consumption in the Islamic Republic of Iran is 7.35 kg per capita and the country is attempting to increase fish consumption among Iranians. The country's fish exports consist of caviar, which constitutes approximately 41 percent of the country's USD81 million in fish exports in 2003. The value of fish imports to the country was USD69 million in the same year (FAO, 2009).

Iraq

Iraq, with an area of 435 052 km^2, has two main regions, flat and mountainous, and a population of 24 million people. Iraq has two main rivers, the Tigris and the Euphrates, which empty into the Arwand River and finally into the Persian Gulf. Iraq has 50 km of coastline in the northwest Persian Gulf. The salt marsh areas of Iraq have been extensively degraded and approximately 90 percent of them have been destroyed. This was caused mainly because of a sharp decline in the inflow of the two main rivers of Iraq into the Persian Gulf, as well as the diversion of the rivers around the marshes causing increased drainage. These salt marshes have been reduced to an area of 1 700 km^2 and are used to support 60 percent of Iraq's fish landings as well as providing a nursery ground for a variety of Persian Gulf fish.

In 2001, approximately 22 800 tonnes of fish was produced in Iraq. In 2003, Iraq imported 1 897 tonnes with a value of USD2 660 000 and exported 17 tonnes with a value of USD97 000. Approximately 20 000 fishermen, 5 000 aquaculturists and 4 500 fish marketers worked in the fisheries industry in 2000. The majority of fish are consumed fresh in Iraq and thus the fish processing sector is not well developed.

The main commercial marine fish species of Iraq are shads (*Tenuolosa* spp.), silver pomfret (*Pampus argenteus*), and different mullet species (*Liza* spp.), and the most important freshwater fishes are cyprinids and *Barbus* spp. Fishing in Iraq is artisanal using trawl, gillnet, cast net and traps. Aquaculture in Iraq is small, is mainly based on Chinese carps and is practised in an area of 7 500 ha with a total production of 2 000 tonnes in 2001 (FAO, 2009).

Kuwait

Kuwait is a flat country with an area of 17 818 km^2 containing no rivers. Kuwait has 195 km of coastline and a population of 2 350 000. In 2001, Kuwait produced 6 000 tonnes of fish. There are 1 400 workers in fisheries and aquaculture, with an additional 2 500 working indirectly in this sector. Some 12 800 tonnes of fish was imported and 640 tonnes exported in 2001. In 2002, the value of fish exports from Kuwait was USD21.2 million and that of imports was USD2.4 million.

Fisheries in Kuwait are mainly artisanal, however, shrimp fishing is practised using both modern and artisanal techniques. Some 90 percent of 3 700 tonnes of finfish are produced by artisanal wooden dhows, while only 45 percent of 2 300 tonnes of shrimp landings are accounted for by artisanal ships. There are 35 industrial trawlers and 33 dhows active in shrimp fishing of Kuwait. The commercially important shrimp species of Kuwait is *Penaeus semiculcatus*, it alone accounts for more than half of the shrimp harvest of Kuwait. There are two processing plants for marine products in Kuwait. The shrimp fishery is managed by imposing a closed season and a no-take zone in Kuwait Bay and 3 miles of coastal waters.

There are an additional 868 fishing vessels targeting finfish as well as 522 intertidal stake nets (hadrah) working in Kuwait (2003 data). The main commercial fish species of Kuwait are silver pomfret (*Pampus argenteus*), hilsa shad (*Tenualosa ilisha*), grunt (*Pomadasys kaakan*), mullets (*Liza* spp.), grouper (*Epinephelus coioides*), seabream (*Acanthopagrus latus*), snapper (*Lutjanuis malabaricus*) and croaker (*Otolithes ruber*). Catches of certain popular species including silver pomfret and hilsa shad have recently decreased. Suggested causes for reduced catch in Kuwait are overfishing and a change in the environment owing to decreased freshwater input resulting from dam construction on the two main rivers of the north Persian Gulf, the Tigris and the Euphrates. The coastal mullet species have also been affected by several occurrences of harmful algal blooms in the region.

Aquaculture in Kuwait includes raising marine seabreams (*Sparus aurata*, *Sparidentex hasta* and *Acanthapagrus latus*), grouper (*Epinephelus coioides*), and brackish-water tilapia (*Oreochromis niloticus*). In 2001, aquaculture production in Kuwait was 195 tonnes. Mariculture is based on cage culture while brackish-water aquaculture is based on agricultural drainwater. Fish fingerlings are mainly imported from Greece, Cyprus, Italy and Bahrain. Fish feed is also imported from the Netherlands and Saudi Arabia.

Shrimp exports have decreased from 90 percent of total catch in the 1980s to 40 percent of total catch in recent years as a result of increased local consumption of shrimp. Workers in the Kuwaiti fishing sector are not all from Kuwait, and the employment provided by fisheries is not regarded as important. However, this sector provides a good opportunity for investment (FAO, 2009).

Oman

Oman has an area of 309 500 km^2 and is located in the Gulf of Oman and the Strait of Hormuz of the Persian Gulf. Oman has a coastline of 3 150 km and a population of 2.6 million. Total fish production in 2003 was 139 000 tonnes, fisheries products imports were 27 000 tonnes and exports were

76 000 tonnes. The value of Oman's fish exports in 2004 was approximately USD103 million and that of imports was USD14 million. There are approximately 35 000 workers in the fisheries and aquaculture sector of Oman, with an additional 6 000 working in dependent industries.

Fisheries are not a major contributor to the economy of Oman. However, it is a significant source of rural activity and employment. In 2004, the total value of fish production of Oman was approximately USD180 million, amounting to 0.6 percent of GDP. Fisheries comprise 2.4 percent of total labour workforce.

The artisanal fisheries industry is made up of 14 000 vessels, which account for up to 85 percent of fishing in Oman, followed by industrial fisheries. Total fisheries production in 2005 was around 150 000 tonnes, consisting of tuna, sardines, emperors, seabreams, groupers, cuttlefish, lobster, shrimp and abalone. The industrial fishing vessels use trawl nets and landed 22 000 tonnes of demersal fish and 3 500 tonnes of pelagics in 2005. They included 31 bottom trawlers and 42 tuna fishers. Some 17 percent of the fish biomass of Oman is present in the Gulf of Oman and the rest is in the Arabian Sea. Lobsters (*Panulirus homarus* and *Panulirus versicolor*) are also fished, mainly by artisanal fishing boats.

Approximately 50 000 tonnes of tuna and other large pelagic fishes, 43 000 tonnes of demersal fish, 50 000 tonnes of sardines and other small pelagic fishes, 233 tonnes of lobster, 57 tonnes of abalone, 12 000 tonnes of cuttlefish, and 500 tonnes of shrimp were landed in 2004. Aquaculture in Oman consists of seabass, seabream and farmed tuna and shrimp. Fish are locally consumed or exported to Europe, Arab and Southeast Asia countries. Oman supplies 60 percent of the Dubai fish market. Fish is an important food item for Omani people, and it is consumed more in rural areas than in cities. The main imported fish items are freshwater fish, salmon, shrimp, and lobster. There are approximately 35 500 workers in fisheries with an additional 3 200 engaged in transporting fish, and 1 300 in fish market jobs (FAO, 2009).

Qatar

Qatar is a flat country, 11 437 km^2 in area, with a population of 600 000 and a coastline of 563 km. In 2001, Qatar produced 8 600 tonnes, imported 4 600 tonnes and exported 2 200 tonnes of fish. Some 4 700 workers are active in fisheries in Qatar. Fishing in Qatar is primarily artisanal, in the past there was an industrial shrimp fishing fleet but the industry shut down in 1993 after a decrease in the species. At present, 98 percent of fish landings in Qatar are finfish, mostly of emperor (*Lethrinus* spp.), grouper (*Epinephlus* spp.), mackerel (*Scomberomorus commerson*) and grunt. There are 515 fishing vessels in Qatar. Fishing methods include gillnet, traps (gargoor) and hook-and-line. Driftnets are illegal but are used. The majority of exported fish is re-exported as 2 100 tonnes of fresh and frozen fish. Imports also increased to 3 820 tonnes in 2001. Qatar had an increase in the catch of grouper and emperor in 2001, with a total catch of 8 863 tonnes. Commercial fisheries in Qatar account for 0.1 percent of its GDP, but owing to its employment capability it is an important sector (FAO, 2009).

Aquaculture includes experimental raising of rabbitfish (*Siganus canaliculatus*) and grouper (*Epinephelus* spp.), but no commercial production. Most landings are consumed locally but some are exported, mostly to Saudi Arabia.

Saudi Arabia

Saudi Arabia is largest country in the Arabian Peninsula, covering more than 80 percent of the peninsula. It is a flat country and is largely covered by desert. The western area is covered by mountains parallel to the Red Sea. There are no rivers with the exception of temporary creeks in Saudi Arabia. It has an area of 1 960 582 km^2, a population of 23 million and a coastline of 2 640 km, of which 580 km is in the Persian Gulf. Although most of the coastal region of Saudi Arabia is located on the Red Sea, the majority of fish production is in the Persian Gulf. In 2003, fish production in Saudi Arabia was approximately 65 000 tonnes. Imports were about 100 000 tonnes, with a value of USD 136 million, and exports were 10 400 tonnes, valued at about USD10.5 million.

Fisheries and aquaculture in Saudi Arabia provide employment for approximately 5 900 people, with an additional 15 000 employed in related activities. The main commercial fish caught in the Persian Gulf are groupers, emperors, scads, mackerel, jacks, shrimp, and kingfish. In 2000, 98 percent of fish production of Saudi Arabia in the Persian Gulf (24 600 tonnes) was contributed by artisanal fisheries. Out of the country's 9 400 artisanal fishing vessels, only 1 800 work in the Persian Gulf; and out of its 183 industrial fishing boats, 34 vessels operate in the Persian Gulf. Saudi Arabia has 1 700 fisheries workers and 7 000 fisheries-related workers in the Persian Gulf. The majority of fisheries workers are from Saudi Arabia, but the workers in fisheries-related activities are mostly non-native. Aquaculture is growing rapidly in Saudi Arabia. Aquaculture production was 8 000 tonnes in 2001. The main fish product is tilapia from brackish-water sources, with 3 900 tonnes in 2001. The culture of shrimp on the Red Sea coast is a growing business in Saudi Arabia. Grouper (*Epinephelus coioides*), seabream (*Sparus auratus*), rabbitfish (*Siganus caniculatus*) and mullet (Mugilidae) are reared in Saudi Arabia, either on a commercial or experimental scale.

Saudi Arabia has three fish-processing plants with modern facilities and a capacity of 100 tonnes. Because stocks of certain popular fish species have decreased and the demand for fish is increasing, the price of most fish products is also increasing. Approximately 14 percent of fish in the Saudi Arabian market are aquaculture products. Most stocks are overexploited. Moreover, some fish species caught in the Persian Gulf have been reduced, such as grouper. In addition to overfishing, illegal fishing (such as fishing of small shrimp by small artisanal boats in shallow waters) and changes in the environmental condition of the Persian Gulf have contributed to the decline. Compared with the oil industry, the input from fisheries to the Saudi Arabian economy is small. The sector is also not very important for job creation because there are few native people working in the sector, but it is significant because of commercial food production and aquaculture as a growing business (FAO, 2009).

Ecosystem approach

The importance of fisheries, marine biodiversity and productive ecosystems in the RECOFI region is clear. Recently the region experienced rapid development in the coastal zone and a loss of potential to sustain coastal populations. An integrated EAF in the region is essential.

Management of fisheries can improve from the current state of open access in many areas and fishing seasons, to a population based totally controlled management that can enhance most commercially important fish species of the region. In this case, the habitat characteristics of each population of a species should be identified and protected. The breeding area, nursery ground and feeding area would be under different management control in order to ensure that enough offspring grow to commercial size for harvest. A fishing ground with a specified season and legal size of fish catch and allowable catch per boat, per day, and per year would be defined, to make sure that no overfishing would happen.

Fisheries and aquaculture in the RECOFI

Artisanal fisheries are of great importance in the RECOFI region as they include a large number of fishers with small incomes, and in many cases fishing is a family business (Figure 3.26). Modern fisheries of various types are also present in the region – however, not at a high-intensity level. The most noticeable of these are the bottom trawlers of the Gulf of Oman, purse seiners, and a few longliners (Figure 3.27). Aquaculture is limited to land-based shrimp culture, and an extensive cage culture of marine species.

Fisheries trends

Most fishing in the region is done using traditional fishing methods (Figure 3.26). This means many fishermen sharing a small amount of catch. However there is a tendency to change the system and use more advanced methods of fishing (Figure 3.27).

Figure 3.26 An example of artisanal beach fishing in the United Arab Emirates
Source: Alyafeyi, 2009.

Compared with the oil industry, the fisheries sector is not regarded as an economically important sector in the region. However, it is regarded as a source of employment and revenue for rural areas. Socially, it is an old system, and has not changed much from its original structure. There are a number of reasons for an overhaul in the fisheries sector, the most important of which is depletion of the main popular species and the growing demand for fish in the region. This is reflected in growing fish imports in some countries, which will probably be followed by other countries.

Figure 3.27 A pair of modern purse seining vessels, Bandar Abbas, Iran (Islamic Republic of)
Source: H. Negarestan.

As fisheries in the region are still in a developing stage, trends do not yet show the effects of climate change. Trends in fisheries show the managerial success of countries of the region in increasing their catch; captured fish have almost doubled in the last decade (Table 3.4). This increase is unlikely to repeat itself in the next decade as the main resources of fish in the region are currently being fully exploited. This is shown by some species such as silver pomfret (*Pampus argenteus*) in Figure 3.28.

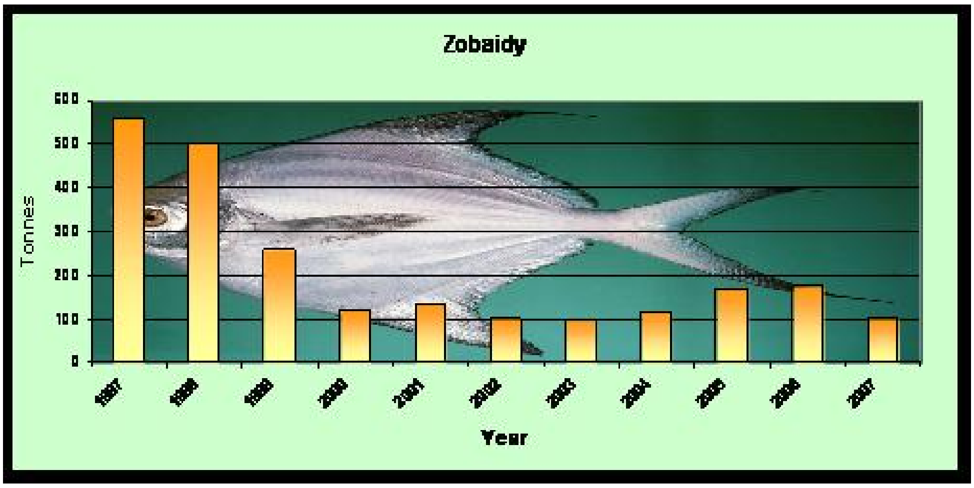

Figure 3.28 Reduced fishing of *Pampus argenteus* in Kuwait
Source: Murad, 2009.

Shrimp are fished from small wooden or fibreglass boats, dhows (Figure 3.29). The trend in shrimp fishing is not similar to fish and it has not increased (Table 3.4). Shrimp have already reached their maximum exploitation potential.

Figure 3.29 A small fibreglass fishing vessel in Bandar Abbas, Iran (Islamic Republic of)
Source: H. Negarestan.

Aquaculture is a rapidly developing industry in the region. It has increased almost five times in the last decade (Table 3.4 and Figures 3.30 and 3.31). It is likely that this industry will continue to increase in the coming decade, if the region can cope with climate change.

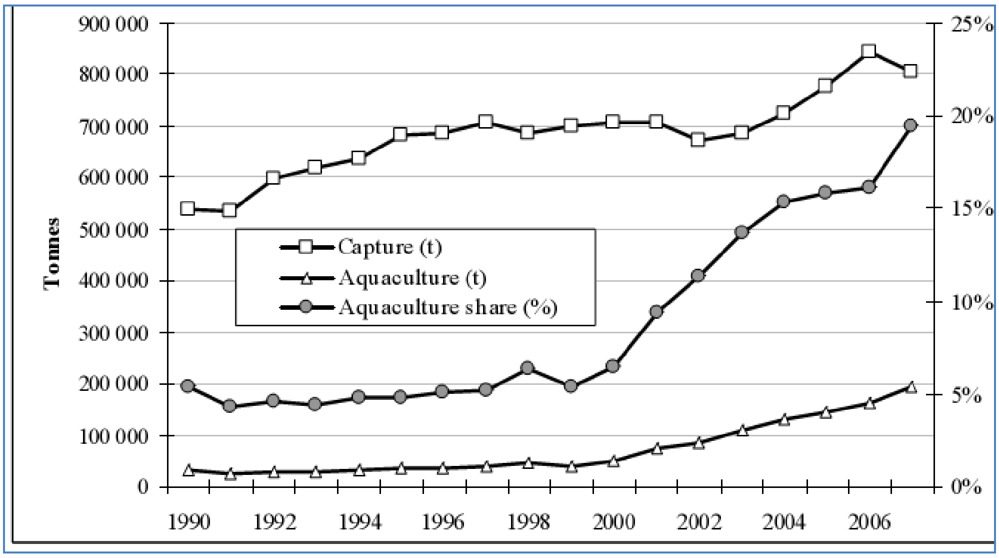

Figure 3.30 Total fisheries production in the RECOFI region (including marine and inland)
Source: RECOFI, 2009.

Table 3.4 Fishery trends of countries of the region, by catch

Country	Marine captured fish		Captured shrimp		Aquaculture		Source
	1997	2007	1997	2007	1997	2007	
	(tonnes)						
Bahrain	7 830	12 222	2 571	2 790	0.5	1.5	FAO, 2009
Iran (Islamic Republic of)	251 380	322 121	7 620	7 450	30 281	158 789	Keymaram, Valinassab & Mojahedi, 2009; FAO, 2009
Iraq	31 302	57 388	–	388	3 400	15 810	FAO, 2009
Kuwait	5 761	2 833	2 066	1 540	204	348	Murad, 2009; FAO, 2009
Oman	118 995	151 744	–	–	–	90	FAO, 2009
Qatar	5 034	15 187	–	–	2	36	Fisheries Department, 2009; FAO, 2009
Saudi Arabia	22 146	42 038	–	–	4 691	18 411	Marine Fisheries Department, 2006; FAO, 2009
United Arab Emirates	114 358	87 000	–	–	2	570	Alyafeyi, 2009; FAO, 2009
Total	453 912	890 533	12 257	12 168	38 580	194 055	

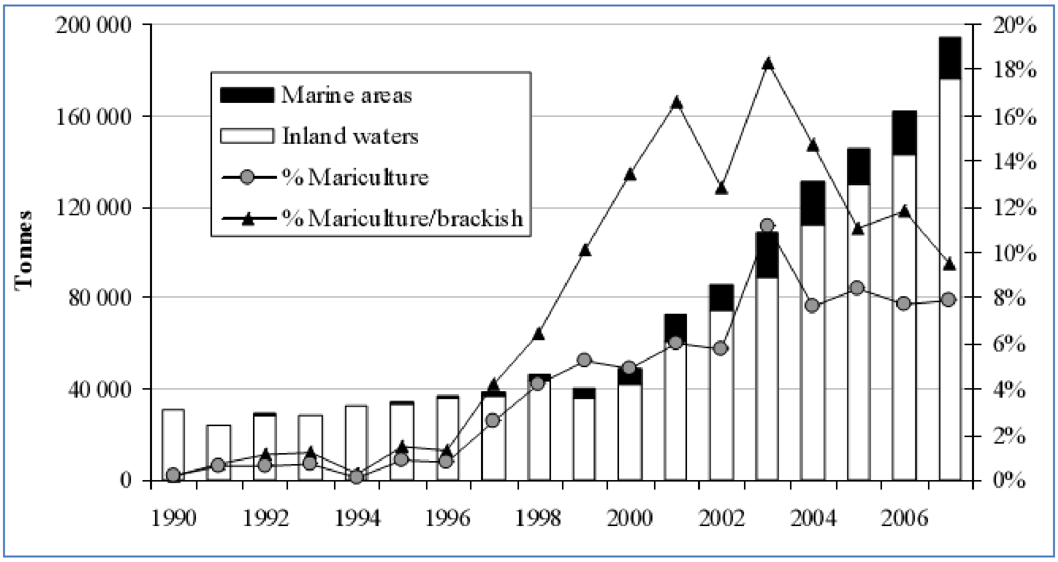

Figure 3.31 Total aquaculture production in RECOFI countries
Source: RECOFI, 2009.

Climate change

Climate change is happening at a growing pace in the world. The RECOFI region was hit by a tropical cyclone called Gonu, causing a large amount of damage. Many areas of the region experience drought. Coral bleaching observations of the region may also be linked to water temperature fluctuations. The *Cochlodinium polykrikoides* harmful algal bloom of 2008 was long-lasting and covered an exceptionally large area. This may have been related to the unusually calm winter in 2008.

When compared with other areas, the RECOFI region has experienced few impacts of four major effects of climate change. However, this may not be the case in the future. The four major effects are:

- temperature change;
- precipitation change;
- sea-level rise;
- extreme events.

Temperature and rainfall changes
The exchange of water between the Persian Gulf and Gulf of Oman is small. In addition, the volume of water that the Persian Gulf receives as freshwater input of the rivers, particularly that of the Arwand River is limited. This river has been reduced as a result of dams and land-based uses, and so a further increase in water temperature and decrease in precipitation may cause serious stress on the populations of commercially important fish species as well as the ecosystems in which they live.

Sea-level rise
Sea-level rise has not significantly affected the RECOFI region. It should be noted that melting of glaciers around the globe is not progressing slowly, and so sea-level rise will affect this region and cause a great amount of damage through loss of land or other damage to the economy, to mangrove forests and other wetland areas, and to the whole ecology of the region.

Extreme events
Cyclone Gonu was a catastrophe, leaving a large amount of damage in its trail, for the first time in the region (Figure 3.32). However, this may not be the last cyclone in the RECOFI region. There are some areas in the world that experience more than two or three cyclones per year.

Figure 3.32 Damage caused by Cyclone Gonu in the Islamic Republic of Iran
Source: Zahmatkeshan and Saadatkhah, 2007.

The “red tide” of 2008 caused many problems for people, fish and other marine organisms. It is unknown whether this will occur again in the future. In 2009, there was a bloom of jellyfish in the Gulf of Oman, causing extensive difficulties for fishers. Without knowing what new invasive, harmful or pathogenic species will migrate to the RECOFI area, it is difficult to prepare. It is necessary to develop mitigation strategies in order to combat these problems.

Fisheries management problems

There are eight countries in the RECOFI region. Fisheries management is practised separately in each country. The present approach to solve fish stock problems is based on concentrating on fishes grouped according to fishing gear. Some species have been given special attention.

The importance of fisheries in the RECOFI region with its rich marine biodiversity and productive ecosystems is clear. In recent decades, the region has experienced rapid development in the coastal zone and a loss of potential to sustain coastal and marine populations of fish. An integrated EAF in the region is necessary. This was the focus of the third meeting of the working group on fisheries management of RECOFI, 20–22 October 2009 in Doha, Qatar.

Results of present management practices
Some popular species are overfished. There are some great fluctuations in short-lived species catch, such as shrimp harvest. Low-income fishers comprise the majority of those in the fishing communities. The sustainability of fisheries is under question. The effectiveness of fisheries management in protecting fish from overfishing is minimal. Illegal and unregulated fishing and trade are out of control. Fishing data deficiencies are a region-wide problem.

Conclusions

Many problems occur as a result of inappropriate management, while other problems occur as a result of climate change. There is a need to change the fisheries management approach in the region, from the present situation to an ecosystem-based approach. In addition, sustainable fisheries for some popular species are under question and need particular attention. There is little evidence that climate change has caused change in the fisheries of the region. However, with the majority of fishers living on low incomes, the RECOFI region is highly sensitive to possible fluctuations caused by climate change in the future.

Aquaculture can be more tolerant of climate change because the system may be more adaptable to change. However, if climate change causes the environment of the region to become more saline, it will present a challenge to aquaculture with regard to finding freshwater.

Recommendations

It is recommended that the countries of the RECOFI region work together in order to build capacity to make a unified road map. This road map would be used for joint work on making strategic plans in order to adopt and mitigate climate change in the next decade. A comprehensive study on possible effects of climate change on the fisheries and aquaculture sector of the region is advisable.

Furthermore, it is recommended that the fishing methods be reviewed and upgraded to less harmful techniques. Fisheries management based on fish habitats with defined fishing grounds, fishing seasons, fish sizes, and limited harvests could result in better fish production in the long run. Unified management in the region can help to bring about better and more profitable fisheries. Aquaculture should be developed and there is room for great development of this sector. However, care is needed to avoid accidental release of exotic species into the coastal waters of the RECOFI region.

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4. EVALUATION OF UNDERSTANDING OF CLIMATE CHANGE, EAF AND EAA

4.1 Pre-workshop questionnaire

The Workshop participants were given a questionnaire prior to attending in order to gain a better understanding of their knowledge of climate change and the EAF and EAA, as well as any initiatives or information dissemination on these topics in their home countries. Eleven questionnaires were returned prior to the Workshop, and the following is an analysis of the results.

Regarding the awareness of climate change, EAA and EAF, more than half of participants who answered the questionnaire were personally aware of these topics prior to coming to the Workshop (Figure 4.1). The depth of knowledge was not known, but none of the Workshop participants were aware of any studies or publications on EAA or EAF in their country (Figure 4.2).

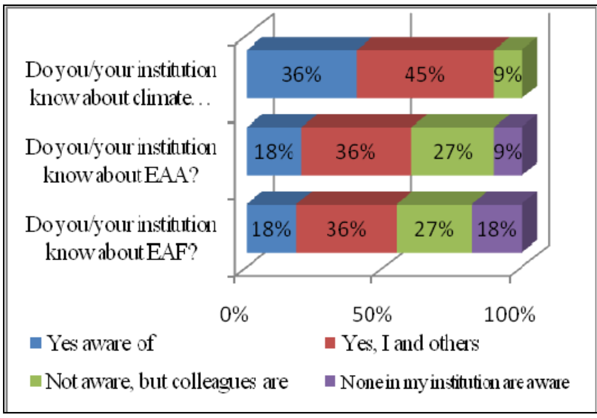

Figure 4.1 Awareness of climate change and the ecosystem approach in the RNEA

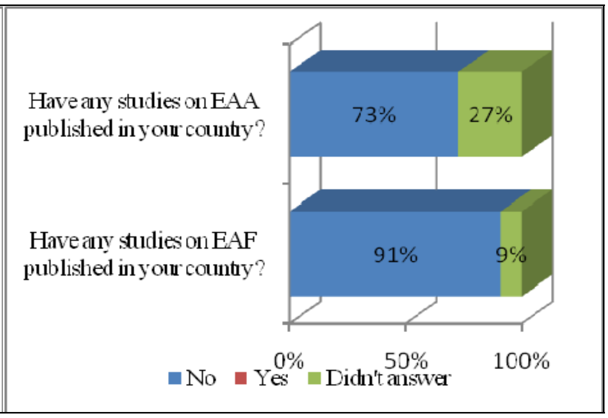

Figure 4.2 Published studies on the EAA and EAF

Government action on adaptation to climate change, as well as the implementation of the EAA and EAF was varied, as detailed in Figure 4.3. While only 27 percent of governments had formally implemented the EAA, 55 percent had implemented the EAF. The disciplines involved in this implementation were mainly fish biology and marine ecology for both. Regarding climate change, 45 percent of governments had taken some kind of action to promote adaptation to the effects of climate change, mainly by the planning, agriculture and forestry, and legislation sectors.

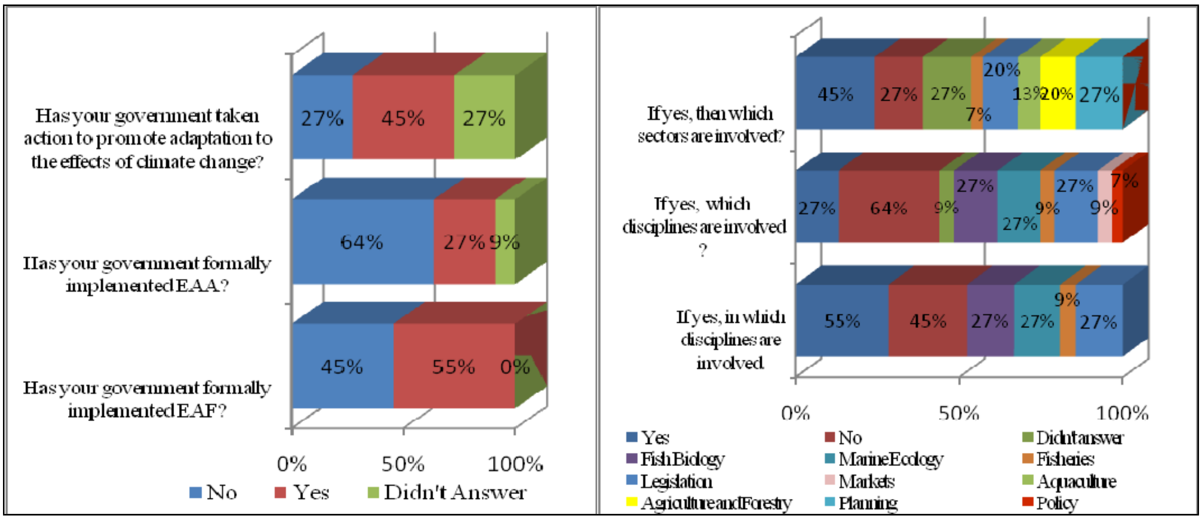

Figure 4.3 Government action on climate change, EAF and EAA

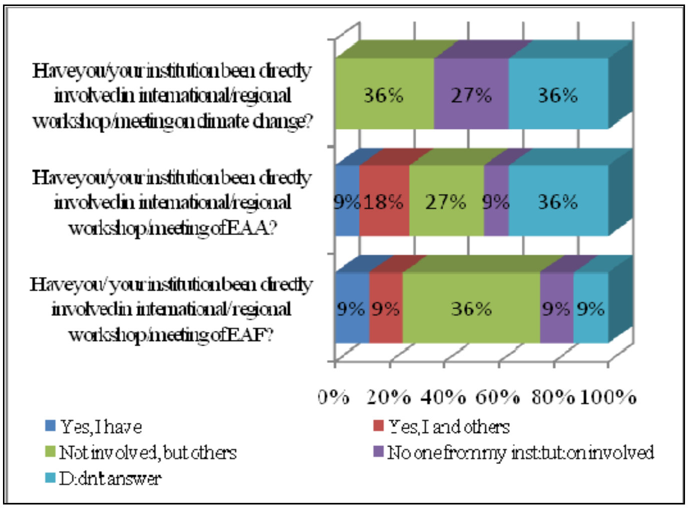

Figure 4.4 Institutional involvement in workshops on climate change, EAF and EAA

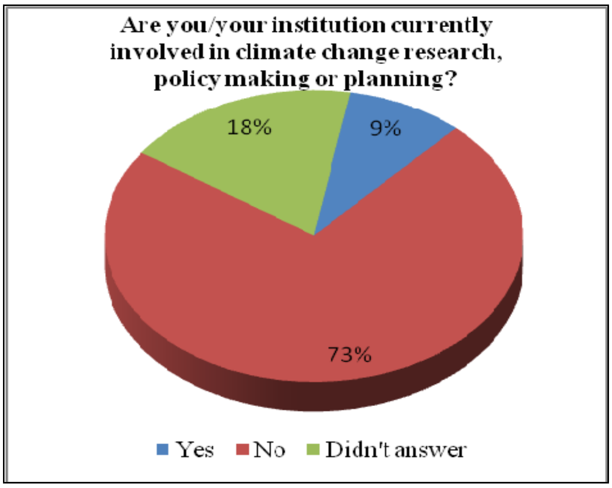

Figure 4.5 Current involvement in climate change

Very few of the participants were directly involved in workshops or meetings on climate change, the EAF or EAA, although many were aware that other colleagues from their institutions were involved (Figure 4.4). Moreover, 73 percent of respondents replied that neither they nor their institution were involved in climate change research, policy or planning (Figure 4.5).

Prior to the Workshop, 73 percent of participants felt that the EAA and EAF were useful tools for climate change adaptation, while 18 percent thought they were useful but needed improvements (Figure 4.6).

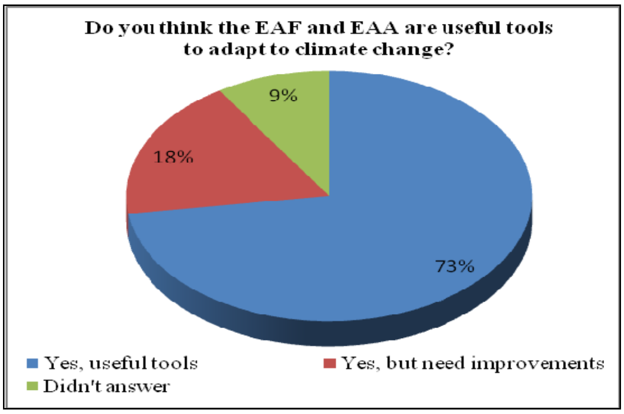

Figure 4.6 Opinions on effectiveness of EAA and EAA for adapting to climate change

4.2 Post-workshop evaluation

Upon completion of the Workshop, participants completed an evaluation questionnaire prior to departure. They were asked questions relating to how the Workshop components served the objectives (Figure 4.7), the quality of the Workshop (Figure 4.8) as well as its value (Figure 4.9) and duration (Figure 4.10). The participants were satisfied for the most part, with the exception of the duration of the workshop, where 54 percent of participants said that the duration of the workshop was insufficient in relation to the workshop components and objectives.

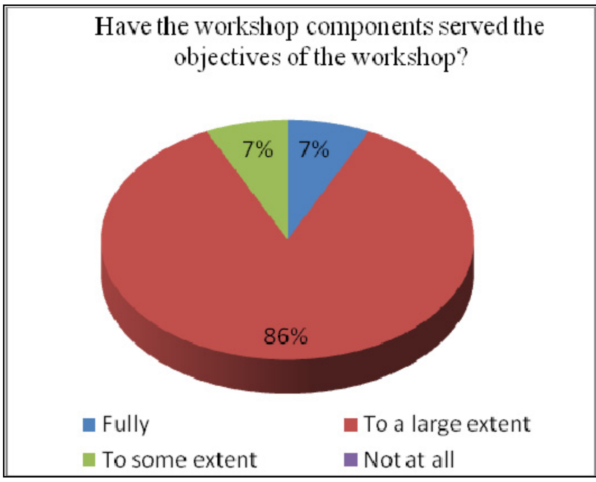

Figure 4.7 Workshop objective achievement

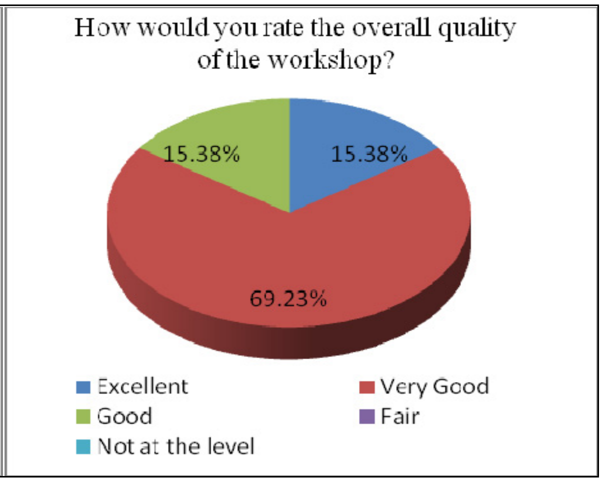

Figure 4.8 Workshop quality

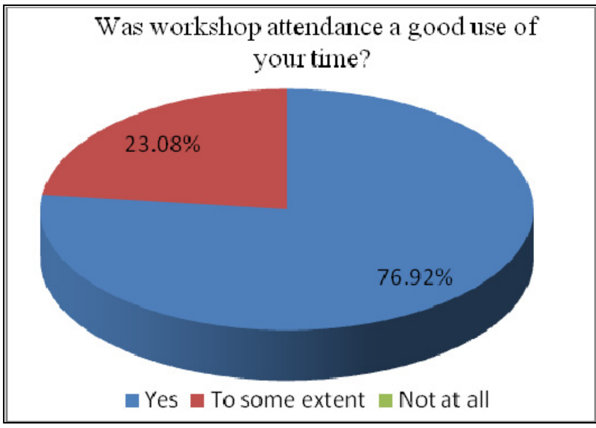

Figure 4.9 Workshop value

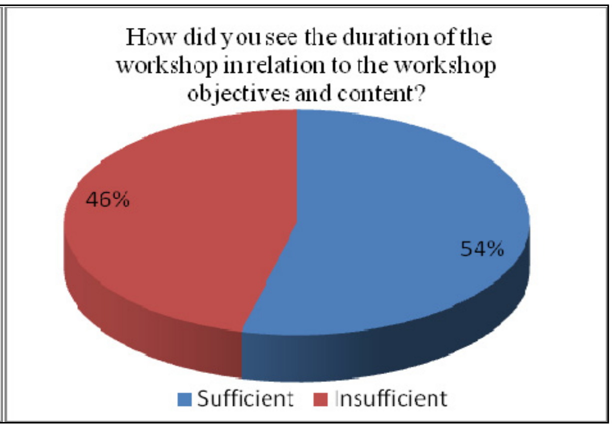

Figure 4.10 Workshop duration vs objectives and content

The final part of the evaluation questionnaire dealt with how the Workshop fared in increasing participant understanding of climate change, EAA and EAF (Figures 4.11 and 4.12). Seventy-five percent of participants said that the Workshop enhanced their understanding of adapting to climate change using the EAA and EAF to a large extent, while the other 25 percent stated to some extent (Figure 4.11). In addition, 50 percent of participants felt that their understanding of climate-change threats to fisheries and aquaculture were much better upon completion of the Workshop, with the other 50 percent responding that it was better. Twenty-five percent of participants said that their understanding of the EAF and EAA was much better, with 75 percent saying their understanding of the EAF was better, and 67 percent saying their understanding of the EAA was better. Only one participant (8 percent) stated that his understanding of EAA was about the same.

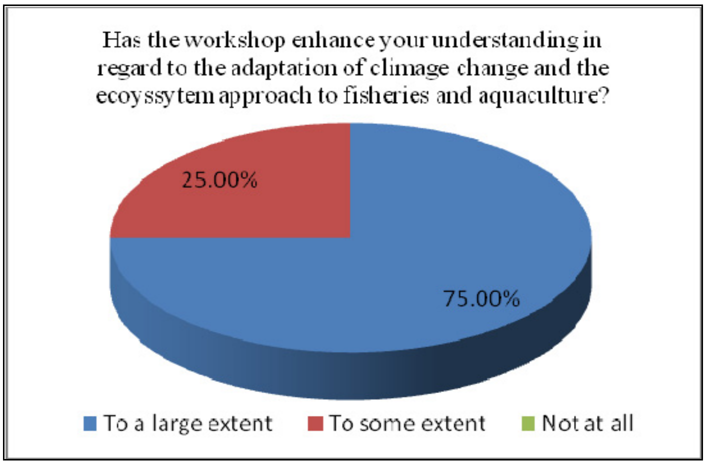

Figure 4.11 Understanding of climate change adaptation, the EAF and EAA

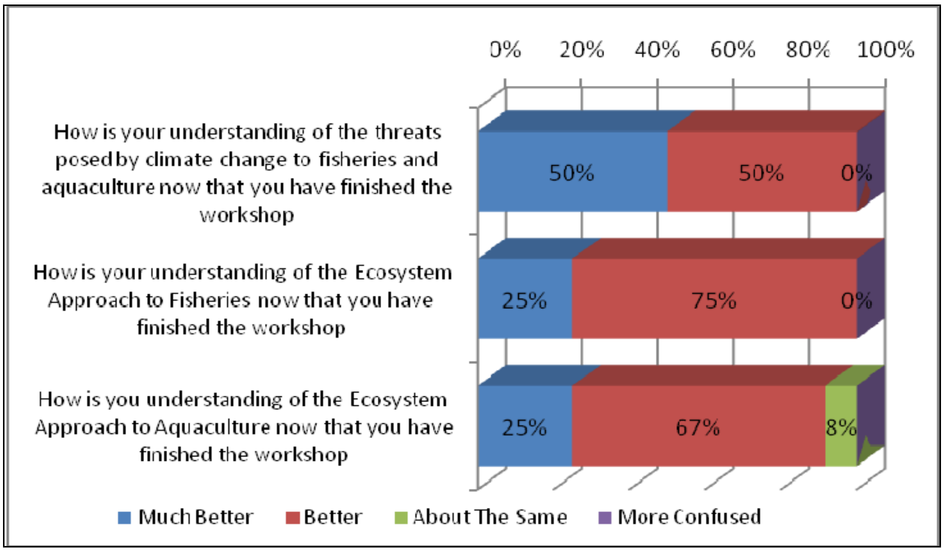

Figure 4.12 Improvements in understanding climate change, the EAF and EAA

The analysis of these results shows that while more than half of the respondents entered the Workshop with an awareness of EAF, EAA and climate change, nearly all of them departed with an enhanced understanding of the issues involved.

APPENDIX I

Finalized agenda

Date	Time	Activity
09/11/09	various	Arrival of the participants
DAY 1 10/11/09	0700–0800	Breakfast
	0830–0900	Registration
	0900–1000	Session 1 – Opening. Chair: Abdel Rahman El Gamal, WorldFish Welcome – Government of Egypt Welcome speech – (on behalf of ADG/RNE of the FAO) Welcome – WorldFish (programme details; housekeeping)
	1000–1030	Group picture and coffee break
	1030–1300 1030–1100 1100–1130 1130–1200 1200–1230 1230–1300	Session 2 –Thematic presentations. Chair: Piero Mannini, FAO Climate change in the Region (Hideki Kanamaru, FAO) Ecosystem-based approach to fisheries (EAF) (Cassandra De Young; Yimin Ye, FAO) Ecosystem-based approach to aquaculture (EAA) (Doris Soto, FAO) Climate change and fisheries (WorldFish/FAO) (Marie Caroline Badjeck and Eddie Allison, WorldFish) Climate change and aquaculture (WorldFish/FAO) (Malcolm Beveridge and Abdel Rahman El Gamal)
	1300–1400	Lunch
	1400–1500	Session 3 – Analysis of country reports. Chair: Malcolm Beveridge Analysis and discussion (Secretariat)
	1500–1530	Break
	1530–1730 1530–1600 1600–1630 1630–1700 1700–1730	Session 4 – Subregional reviews. Chair: Malcolm Beveridge Mauritania/Morocco (Abdellatif Orbi, INRH) Mediterranean (Malika Bel Hassen-Abid, INSTM) Red Sea and Gulf of Aden (Mohammed Abou Zaid, Al Azhar University) The RECOFI (Hossein Negarestan, IFRI)
	1730–1740 1740–1800	Closing session. Meeting of Secretariat
	1900–2000	Dinner for participants staying in Abbassa
DAY 2 11/11/09	0700–0800	Breakfast
	0830–1000	Session 5 – Thematic Working Groups: Identify climate change impacts on fisheries and aquaculture using ecosystem approach. Distribution of post-workshop evaluation form Divide groups and outline tasks Identify likely regional climate change impacts on fisheries and aquaculture and time-scales; summarized as bullet points
	1000–1030	Coffee break
	1030–1200	Session 5 (ctd.) – Thematic Working Groups: Identify climate change impacts on fisheries and aquaculture using ecosystem approach. Summarize as bullet points
	1200–1300	Session 5 (ctd.) Report from thematic working groups to plenary, and discussion. Chair: Cassandra de Young
	1300–1400	Lunch
	1400–1530	Session 6 – Thematic Working Groups: Identify adaptation strategies to climate change impacts for fisheries and aquaculture.
	1530–1600	Coffee break
	1600–1730	Session 6 (ctd.) – Thematic Working Groups: Identify adaptation strategies to climate change impacts for fisheries and aquaculture.
	1730–1800	Meeting of Secretariat
	1900–2030	Workshop dinner

DAY 3 12/11/09	0700–0800	Breakfast
	0830–1000	Session 6 (ctd.) – Report from thematic working groups to plenary, and discussion. Chair: Piero Mannini
	1000–1030	Coffee break
	1030–1330	Session 7 – Thematic Working Groups: Identify regional and subregional capacity to adapt to climate change impacts. Chair: Doris Soto
	1330–1430	Lunch
	1430–1530	Session 7 (ctd.) – Report to plenary on the regional and subregional capacity to adapt to climate change impacts
	1530–1600	Coffee break
	1600–1630	Session 8 – Closure Chair: Secretariat Collection of post-workshop evaluation forms
	1630–1700	Meeting of Secretariat
	1900–2000	Dinner for participants staying in Abbassa

APPENDIX 2

List of attendees

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ISBN 978-92-5-106822-9 ISSN 2070-6065

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I2146 E/1/03.11