Building resilience for adaptation to climate change in the fisheries and aquaculture sector

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INTRODUCTION

It is often overlooked that over 500 million people depend, directly or indirectly, on fisheries and aquaculture for their livelihoods. In addition, fish provide essential nutrition for over 4 billion people and at least 50 percent of animal protein and essential minerals to 400 million people in the poorest countries. Trade is also an important characteristic of the fisheries and aquaculture: fish products are among the most widely traded foods, with more than 37 percent by volume of world production traded internationally. But climate change is bringing an ocean of change to the world's fisheries, which are already in crisis from overfishing and poor management.

Multiple drivers of change and the role of climate change

Change, whether positive or negative, is an integral part of fisheries and aquaculture systems and comprises those drivers that will impact the aquatic systems' biological processes through, for example, changes in water quantity and quality, temperature, salinity, oxygen, acidity, fishing pressure and natural habitats, as well as drivers of change that impact human choices in their use of aquatic resources, such as changes in governance structures, input and output prices, technological change, emergencies and cultural contexts. If not integrated into the management system, the impacts of these drivers of change may be profoundly negative on long-term sustainability – many capture fisheries worldwide have declined sharply in recent decades or have already collapsed from overfishing. Climate change will compound existing pressures on fisheries and aquaculture and the question of how to meet increasing demand for fish in the face of climate change poses a great challenge to fisheries and aquaculture management.

Since most aquatic animals are cold-blooded, their metabolic rates are strongly affected by environmental conditions, especially temperature.[1] Changes in temperature can have significant influence on the reproductive cycles of fish, including the speed at which they reach

[1] Summary of expected impacts revised from FAO, 2009a – a review of scientific knowledge on climate change impacts and implications for fisheries and aquaculture.

sexual maturity, the timing of spawning and the size of the eggs they lay. The projected increasing temperatures will likely result in changes in distribution of both freshwater and marine species, with most marine species ranges being driven towards the poles, expanding the range of warmer-water species and contracting that of colder-water species. Examples of temperature-related impacts specific to aquaculture would be related to temperature comfort zones of farmed species and the increased spread of farmed fish diseases directly linked to increased temperatures. Whether positive or negative, these changes will have social and economic impacts on the fisheries and aquaculture industries and communities – possibly through new mismatches between where the fishing happens and where it is landed or processed, changes in farm profitability either through inputs needed or productivity of individual farms, or through the disappearance of traditional sources of local food and livelihood security. At the macro scale, there will likely be implications for international fisheries management owing to changes in the distribution of transboundary fish stocks, for example.

Greenhouse gas (GHG) accumulation is also increasing the acidification of oceans, with potentially severe consequences for shellfish and squid, mangroves, tropical coral reefs and cold-water corals. Among other services, coral reefs are home to 25 percent of all marine fish species, but changes in water chemistry may directly impact on their ability to produce their skeletons, directly impacting reef-based fisheries alongside tourism, medicine, etc.

Rising sea levels will displace brackish and fresh waters in river deltas, wiping out some freshwater aquaculture practices and destroying wetlands, but also creating new environments and some opportunities (e.g. for brackish aquaculture species). **Increased storm activity** (intensity and occurrence) endangers the lives of fishers, fishfarmers and coastal/riparian/lacustrine communities directly, can cause damage to fisheries and aquaculture infrastructure and housing, and presents additional threats for coral reefs and mangroves. More subtly, storms stir waters, causing temperatures and nutrients levels to change along the water column, having likely consequences for species distribution. Storms and floods will also increase the risks that farmed species escape, having potential impacts on farm profitability and genetic biodiversity in the natural systems.

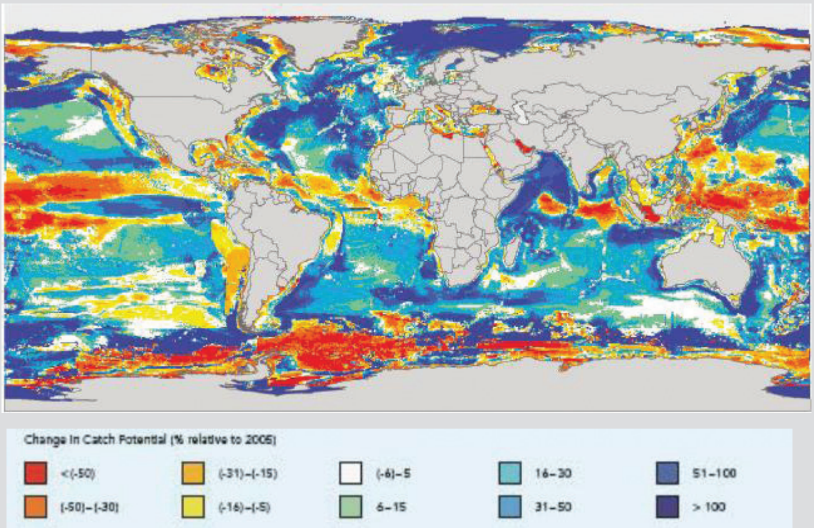
Fisheries- and aquaculture-dependent economies, coastal communities and fishers and fishfarmers are expected to experience the effects of climate change in a variety of ways. In addition to climate change impacts not stemming from the aquatic systems that they may face, such as increased risks of human diseases relating to increased temperatures, these communities are closely tied to changes in the aquatic world. These might include: displacement and migration of human populations from low-lying areas to less risky areas or to follow changes in fish distributions; effects on coastal communities and infrastructure due to sea level rise; and increased losses throughout the production and distribution chain owing to changes in the frequency, distribution or intensity of weather events. It must be noted that many fishing and coastal communities already subsist in precarious and vulnerable conditions because of poverty and rural underdevelopment, with their well-being often undermined by overexploitation of fishery resources and degraded ecosystems. As the vulnerability of fisheries and fishing communities depends not only on their exposure and sensitivity to change, but also on the often lacking ability of individuals or systems to anticipate and adapt, these communities tend to be among the most vulnerable.

BOX 1

Predicted changes in fisheries catch potential

Results of a modelling exercise on the latitudinal shift in catch under different greenhouse gas concentrations scenarios indicate that there could be drastic changes, with the tropical countries suffering up to a 40 percent drop in catch potential and high-atitude regions enjoying as much as a 30 to 70 percent increase in catch potential.

Change in maximum marine catch potential from 2005 to 2055 under the climate change scenario where greenhouse gas concentrations are doubled by the year 2100



How would the current top fishing countries fare under this high emissions scenario? The model predicted that, by 2055, exclusive economic zones (EEZ) average catch potentials in Nordic countries (such as Norway, Greenland and Iceland) would increase by 18 to 45 percent; in the Alaska and Russia Pacific EEZ by around 20 percent, and decline by various degrees in most EEZ around the world, with Indonesia having the largest projected decline of the group – an over 20 percent decline across the 45 species currently targeted within its EEZ.

Source: Cheung *et al.* (2010).

In addition, as nations implement adaptation and GHG mitigation actions across all sectors, there may also be unplanned consequences (trade-offs and synergies) of actions in other sectors that drive changes within the aquatic food production systems. For example, national GHG mitigation efforts may include the development of aquatic renewable energy sources, such as through capturing energy in tides, currents, waves, wind, hydropower and aquatic biofuels. How these mitigation strategies impact the aquatic systems is not always

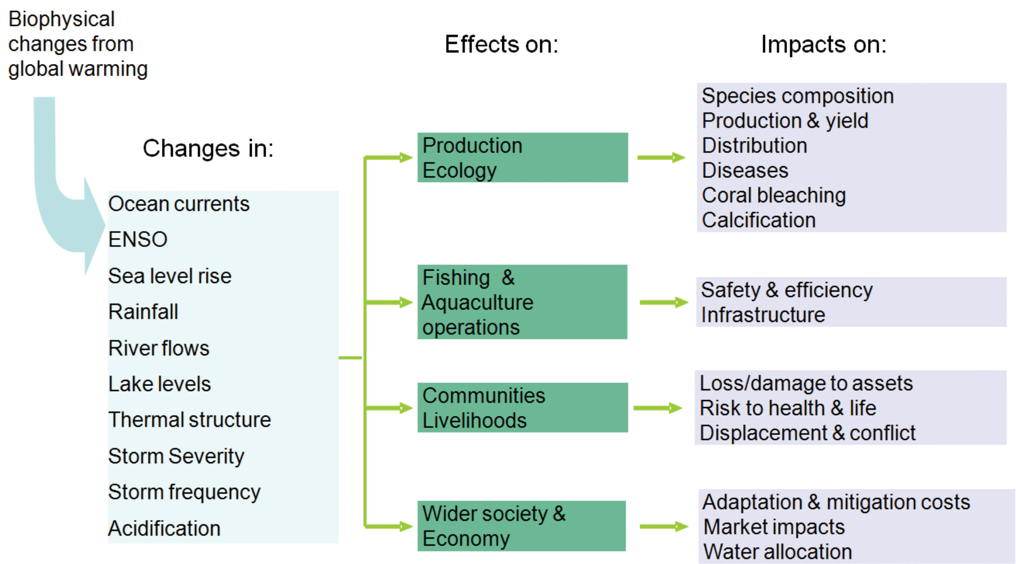


Figure 1. Schematic representation of climate change impact pathways to fisheries and aquaculture systems
Source: Badjeck *et al.* (2010).

well understood but, for example, the building of dams for hydropower could undermine fisheries and aquaculture systems downstream as water flows will be greatly altered. Drivers of change stemming from the need of other sectors to adapt to climate change will also arise. For example, agriculture production in areas faced with increasing water scarcity may need to divert water for irrigation purposes, impacting lake and river water levels and flows. In addition, the often open access nature of fisheries lends itself to being a planned or unplanned adaptation strategy for other sectors. For example, by 2007, 80 percent of conflict-affected refugees in the Democratic Republic of the Congo were successfully living from fishery and agriculture activities after receiving training in the new skill sets (UNHCR, 2007) and aquaculture is often looked to as a potential adaptation alternative for fisheries in the face of decline catches. From the unplanned side, "emergency fishing" is a common strategy for displaced persons (see FAO, 2007, for example). How these actions change, for example, water availability or quality and productivity or ecosystem functioning will need to be monitored and planned for.[2]

VULNERABILITIES TO CHANGE

According to IPCC (2001), vulnerability to change is a function not only of the degree of exposure to climate change but also of the sensitivity of a system to changes in climate – "the degree to which a system will respond to a given change in climate, including beneficial and harmful effects" and adaptive capacity – "the degree to which adjustments in

[2] See, for example, Leonhard, Stenberg and Stottrup (2011) for an assessment of impacts of offshore wind farming on fish communities.

practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate". Given that fisheries and aquaculture are part of a complex social-ecological system, there is no one set method for putting the IPCC vulnerability model into practice. The application of the IPCC model will depend on who's vulnerability is of interest for adaptation planning, at what scale is the adaptation planning to take place, as well as other pragmatic factors such as data availability. For example, Allison *et al.* (2009) were interested in the vulnerability of national economies to climate change implications to fisheries (see Box 2). Alternatively, one might be interested in the vulnerability of species, food webs or ecosystems (see Bell *et al.*, 2011 for examples of tuna, tuna food web, coral reef, mangroves, freshwater habitats and fisheries vulnerabilities in the tropical Pacific islands). Cinner *et al*. (2012) have applied the IPCC model to social-ecological coral reef-based fishing communities, imbedding the coral reef vulnerability to climate change into the fishing communities' vulnerability to changes stemming from within the coral reef systems.

Although adaptation planning can happen given a rapid appraisal approach to understanding vulnerabilities, the more detailed and in-depth the vulnerability analysis, the better targeted the adaptation planning. For example, recent community-level vulnerability work within 29 reef-dependent coastal communities across five western Indian Ocean countries showed large differences in adaptive capacities across the communities when facing the same climate change impact; requiring "nuanced" policy interventions to reduce vulnerability within each community (Cinner *et al.,* 2012). Within communities, there will also be vulnerability differences by age, gender and marginalized groups, so, ensuring that the vulnerability assessment includes these individuals will also provide better targeted adaptation planning.

What is interesting to note is that, even in the face of positive opportunities stemming from climate change, those vulnerable to change may not be able to take advantage of these potential benefits, whether it be, perhaps, because of lack of knowledge or access to new markets or overly rigid management system.

PREPARING AND RESPONDING TO THE IMPACTS: ADAPTATION TO CLIMATE CHANGE THROUGH BROADER VULNERABILITY REDUCTION

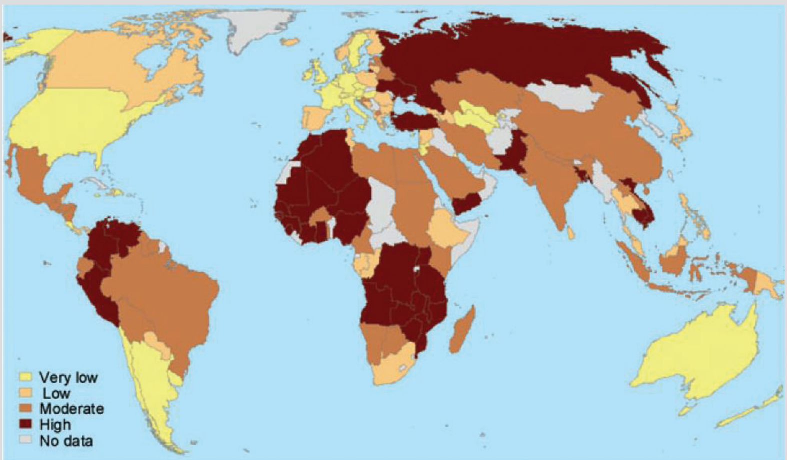
Although determining a direct causal relationship between climate change and impacts on fisheries and aquaculture may not often be feasible owing to costs of research or complexity of the system under question, there is already much that can be done within a "no regrets" approach to reducing vulnerability. Fortunately, we are not without knowledge on how to build and maintain resilience[3] of the natural and human systems and, in the fisheries and aquaculture sector, there is no lack of guidance – the 1995 Code of Conduct for Responsible Fisheries (FAO, 1995) clearly demonstrates the principles and standards applicable to the conservation, management and development of the world's fisheries, including aquaculture, such as the prevention of overfishing, the minimization of negative impacts to aquatic

[3] Although the resilience concept is often limited to the ability of a system to "bounce back" to its previous state when faced with a shock, it is often the case that simply returning to the status quo is not enough and efforts to improve the ecological, social and economic well-being of the system before and after shocks must happen. Building back better is a term used in disaster risk management to reflect the need to not only respond to emergencies but to put in place disaster risk management that better prepares for the next potential emergency (http://www.preventionweb.net/files/13247_i0772e001.pdf).

BOX 2

A global mapping of national economies' vulnerability to climate change impacts on fisheries

The first global attempts at defining national economies' vulnerability to the impacts of climate change on fisheries are represented below. Based on the IPCC definition of vulnerability and available data, national-level vulnerability indicators for the fisheries sector were calculated for 132 countries and relatively vulnerability rankings developed. The analysis revealed that 16 African least developed countries (LDC) and three Asian LDC were deemed to be among the relatively highly vulnerable countries. Unfortunately, data unavailability precluded many small island developing states from the analysis but, given their high dependence on fisheries, low adaptive capacity and high exposure to extreme events, one would expect high relative vulnerability rankings among these countries.



While many African marine coastal fisheries are not likely to face huge physical impacts, the region's adaptive capacity to respond to climate change is relatively low and fish consumption high, rendering communities there highly vulnerable even to minor changes in climate and temperature. In the northern hemisphere, the Russian Federation and Ukraine were ranked highly vulnerable owing to a predicted high degree of warming and a low adaptive capacity.

Source: Allison *et al.* (2009) and Daw *et al.* (2009).

ecosystems and local communities, and the protection of human rights to a secure and just livelihood. The ecosystem approach to fisheries and aquaculture (EAF/EAA) (see FAO 2003, 2009b; 2010). provides the approach, strategies and tools for implementing the Code and implies a holistic, integrated and participatory way to managing fisheries and aquaculture systems (see Box 3).

BOX 3

A brief overview of the ecosystem approach to fisheries and aquaculture

The EAF/EAA places its focus on fisheries and aquaculture management but broadens the perspective beyond seeing a fishery as simply "fish in the sea, people in boats" or an aquaculture farm as a disjointed fish production process, beyond consideration only of commercially important species, and beyond management efforts directed solely at the fish harvesting/farming process. EAF/EAA requires the inclusion of interactions between the core of the fishery – fish and fishers/fishfarmers – as well as other elements of the ecosystem and the human system (i.e. is a social-ecological system) and is aligned with the more general ecosystem approach but is focused on supporting the sector's participation in broader multisectoral application of the ecosystem approach:

> *The purpose of an EAF/EAA is to plan, develop and manage fisheries and aquaculture 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.*

The EAF/EAA is the mechanism to attain sustainable development in fisheries and aquaculture – stressing holistic, integrated and participatory processes. Accordingly, application of the EAF/EAA should address the following principles:

- apply the precautionary approach when faced with uncertainty;
- use best available knowledge, whether scientific or traditional;
- acknowledge multiple objectives and values of ecosystem services;
- embrace adaptive management;
- broaden stakeholder participation;
- use the full suite of management measures;
- promote sectoral integration and interdisciplinarity.

Sources: FAO (2003; 2009b).

USING EAF/EAA TO IDENTIFY KEY CLIMATE CHANGE ISSUES

As the EAF/EAA calls for a broader and more holistic approach to analysis and management actions, the EAF/EAA process itself assists in the monitoring of climate change impacts. A key step in any EAF/EAA process includes the identification of issues (and their prioritization through a risk assessment) that need to be addressed by management, including all direct and indirect impacts of the fishery/farm on the broader system. Included in this process is the identification of any non-fisheries/aquaculture issues (those that are external to the fisheries/aquaculture management system) that are affecting, or

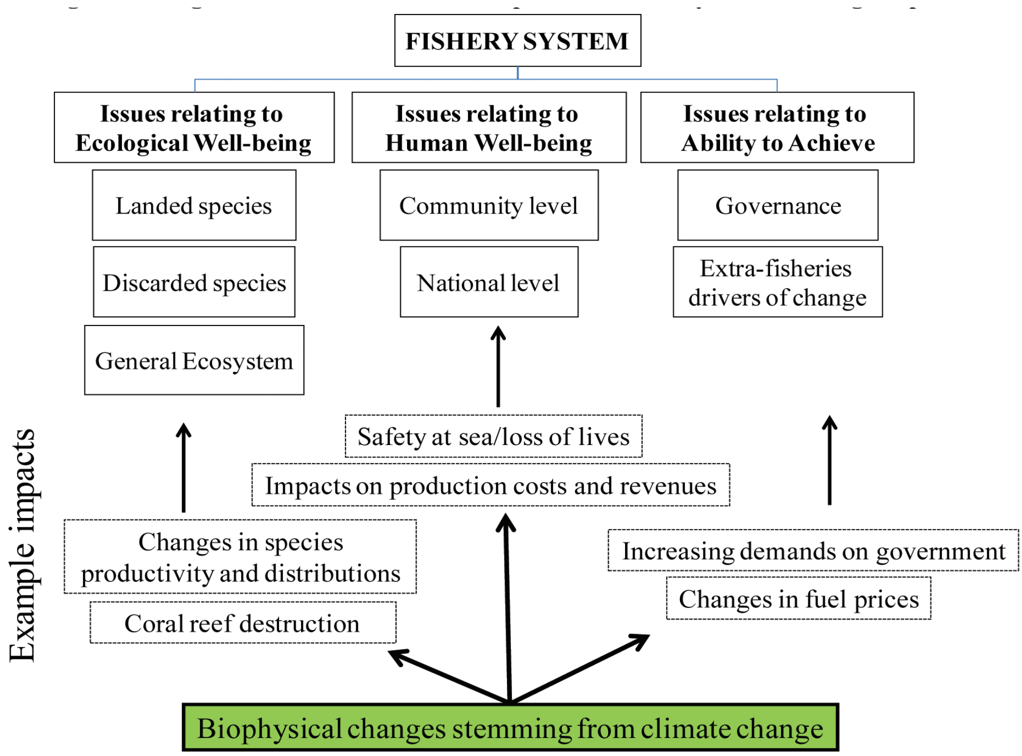


Figure 2. Using the EAF issue identification process to identify climate change impacts

could in the future affect, the performance of the system and its management such as climate variability and change (see Figure 2). Having the broadened and integrated monitoring system that an EAF/EAA would imply would allow for the monitoring of changes in the aquatic ecosystems and their impact pathways through the fisheries and aquaculture systems.

USING EAF/EAA TO BUILD RESILIENCE TO CLIMATE CHANGE

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 FAO Code of Conduct for Responsible Fisheries and the EAF/EAA. Progress in this direction would be an important contribution to maintaining biodiversity, preserving the resilience of human and aquatic systems to change, and improving our 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/EAA include:

- creating resilient ecosystems, human, and governance communities through (i) decreasing the exposure of the sector by increasing the aquatic systems' resilience, (ii) decreasing the communities' sensitivities to change; as well as by (iii) increasing the sector's adaptive capacity;

- supporting intersectoral collaboration (e.g. integrating fisheries and aquaculture into national climate change adaptation and disaster risk management (DRM) strategies and supporting integrated resource management, such as integrated coastal zone or watershed management, water planning);
- promoting integrated monitoring and information systems - incorporating scientific and local knowledge sources;
- improving general awareness of climate change within and outside the sector;
- promoting context specific and community-based adaptation strategies;
- avoiding “mal-adaptations” (e.g. overly rigid fishing access regimes that inhibit fisher migrations, adaptation actions that would increase fishing effort in an over-fished fishery);
- embracing adaptive management, decision-making under uncertainty and the precautionary approach; and
- Promoting natural barriers and defenses rather than hard barriers that would impact the ecosystem.

Improving the general resilience of the fisheries and aquaculture system will reduce its vulnerability to climate change. For example, biodiversity rich systems are less sensitive to change than overfished and biodiversity-poor systems. Healthy coral reef and mangroves systems provide, inter alia, natural barriers to physical impacts. Fisheries and aquaculture-dependent communities with strong social systems and a portfolio of livelihood options have higher adaptive capacities and lower sensitivities to change. Larger-scale production systems under effective governance systems and having high capital mobility would tend to be more resilient to change.

In addition, by assisting in improving our understanding about the role of aquatic systems as natural carbon sinks and how fisheries impact this role, and by supporting a move to environmentally friendly and fuel-efficient fishing, aquaculture and post-harvest practices, implementing the EAF/EAA will also feed into global greenhouse gas mitigation efforts.

Interestingly, a recent modelling exercise (Merino *et al*., 2012) to determine the capacity of the global fisheries and aquaculture sector to meet increasing demand for fish products while facing the high emissions scenario of the IPCC (A1B) concluded that meeting current and larger consumption rates is feasible but only if fish resources are managed sustainably and the animal feeds’ industry reduces its reliance on wild fish. The authors note a strong caveat that ineffective fisheries management and rising fishmeal prices driven by greater demand could, however, compromise future aquaculture production and the availability of fish products. Putting into place robust and effective management now is the key to meeting future and uncertain challenges.

PLANNED ADAPTATION

In addition to restoring and building up of the ecological system’s natural resilience, the fisheries and aquaculture sector may also rely to a certain extent on risk spreading or reduction tactics, such as livelihood diversification, disease and disaster risk management, and creative combinations of public and private insurance tools. At a different scale, traditional policy and management planning and tools will need to be “climate proofed”, such as by allowing spatial and temporal tools – protected areas and closed seasons, for example – to adapt to climatic variables or by explicitly incorporating decision- making under uncertainty into management plans. Management planning will need to evaluate, for example, how shifts from an open access situation towards defined and stable access rights might affect fishers' use of migration as an adaptation strategy when facing changes in species distributions.[4] At the regional level, regional agreements among countries sharing transboundary stocks will also need to be adjusted as shifts in stock distributions and changes in productivity occur.[5]

Technical innovation will also provide some adaptation options, such as the breeding of saline resistant aquaculture species to confront sea level rise, the development of storm resistant fish farming systems (e.g. sturdier fish cages) and the widespread use of information technology to share weather as well as market information. Fishing vessels of all sizes may be rendered more stable to allow for fishing further away from the coastal area to follow targeted species and resist inclement weather. Fish aggregating devices may be used to lure fish back within the traditional fishing grounds.

Proper aquaculture zoning mechanisms at the watershed level, biosecurity frameworks, risk analysis and strategic environmental assessments (FAO, 2009c) that take into account the added effects on aquaculture farms would enable the sector 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).

Diversification within aquaculture, and especially exploring new opportunities in mariculture, potentially offers new adaptation options. By moving away from freshwater systems, both the impacts on water resources and the competition with other sectors for its use would be 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 a greater exposure to rougher seas would be a trade-off to such an adaptation action.

Tables 1 and 2 present examples of adaptation options available within fisheries and aquaculture, the choice of which would depend on the context at hand and the social, economic and ecological costs and benefits.

CONCLUSIONS

Climate change is adding to the sense of urgency within fisheries and aquaculture for the need to improve the resilience of human and aquatic systems. The Code of Conduct for Responsible Fisheries and the Ecosystem Approach to Fisheries and Aquaculture provide many principles, strategies and tools that can be implemented today to lessen these social-ecological systems' exposure and sensitivity to climatic change as well as increasing their adaptive capacities.

Application of the EAF/EAA will help to ensure that effective stakeholder involvement in both monitoring changes and adaptation planning becomes the default approach to ensuring resilience of the socio-ecological systems and to minimize unintended

[4] See, for example, Badjeck *et al.* (2009) for a review of institutions and management frameworks under climate change in Peru.

[5] See, for example, the proposal of Bell, Johnson and Hobday (2011) on ways to adjust an existing regional tuna fishing effort scheme in the face of climate change-related shifts in tuna distribution.

Table 1: Example of adaptation to climate impacts on fisheries

Impact on fisheries	Potential adaptation measures
Reduced fisheries productivity and yields	Access higher value markets Increase effort or fishing power*
Increased variability of yield	Diversify livelihood portfolio Insurance schemes Precautionary management for resilient ecosystems Implementation of integrated and adaptive management
Change in distribution of fisheries	Private research and development and investments in technologies to predict migration routes and availability of commercial fish stocks* Migration*
Reduced profitability	Reduce costs to increase efficiency Diversify livelihoods Exit the fishery for other livelihoods/investments
Increased vulnerability of coastal, riparian and floodplain communities and infrastructure to flooding, sea level and surges	Hard defences* Managed retreat/accommodation Rehabilitation and disaster response Integrated coastal management Infrastructure provision (e.g. protecting harbours and landing sites) Early warning systems and education Post-disaster recovery Assisted migration
Increased risks associated with fishing (e.g. safety at sea)	Private insurance of capital equipment Adjustments in insurance markets Insurance underwriting Weather warning system Investment in improved vessel stability/safety Compensation for impacts
Trade and market shocks	Diversification of markets and products Information services for anticipation of price and market shocks
Displacement of population leading to influx of new fishers	Support for existing local management institutions
Various	Publicly available research and development

*Adaptations to declining/variable yields that directly risk exacerbating overexploitation of fisheries by increasing fishing pressure or impacting habitats.
Source: Daw *et al.* (2009).

consequences of adaptation and mitigation actions. Integrated adaptation planning and implementation within a systems approach will not only allow for the specificity needed within each sector but also for addressing issues shared across sectors within a broader system.

We will need to continue efforts to improve and downscale our understanding of current vulnerabilities and adaptation strategies of the sector to prepare the sector for its own climate change planning and also to enable the sector to participate in national climate change planning, including providing feedback on the impacts of adaptation and mitigation actions from other sectors.

Technological innovation, public and private insurance schemes and disaster risk management will also provide necessary adaptation options but putting into place robust and effective management now will be the key to ensuring and enhancing the benefits derived from fisheries and aquaculture.

Table 2: Example of adaptation to climate impacts on aquaculture

Impacts	Adaptive measures
Temperature rise above optimal range of tolerance	Better feeds; selective breeding for higher temperature tolerance
Temperature change increased growth rates; higher production	Increase feed input and better management
Eutrophication and upwelling; mortality of stock	Better planning: farm/cage siting conforming to ecosystem carrying capacity, regular monitoring
Increased virulence of dormant pathogens	None; monitoring to prevent health risks
Limitations on fishmeal & fish oil supplies/price	Fishmeal & fish oil replacement; new forms of feed management; shift to non-carnivorous commodities
Coral reef destruction	None; but shifting from harvesting to breeding of coral reef species may impact positively by reducing fishing pressure and harmful fishing practices; improving reef resilience
Salt water intrusion	Shift upstream stenohaline species- costly; new euryhaline species in old facilities
Loss of agricultural land	Provide alternative livelihoods- aquaculture: capacity building and infrastructure
Reduced catches from artisanal coastal fisheries; loss of income to fishers	Reduced feed supply; but encourages use of pellet feeds-higher cost/ environmentally less degrading
Increase of harmful algal blooms	Mortality and increased human health risks by eating cultured molluscs
Indirect influence on estuarine aquaculture through changes in brook stock and seed availability	None
Impact on calcareous shell formation/ deposition	None
Limitations for water abstraction	Improve efficacy of water usage; encourage non-consumptive water use aquaculture, e.g. cage-based aquaculture and/or mariculture
Water retention period reduced	Use of fast growing fish species; increase efficacy of water-sharing with primary users e.g. irrigation of rice paddy
Availability of wild seed stocks reduced/period changed	Shift to artificially propagated seed; extra cost
Destruction of facilities; loss of stock; loss of business; mass scale escapement with the potential to impacts on biodiversity	Encourage uptake of individual/cluster insurance; improve design to minimize mass escapement; encourage use of indigenous species to minimize impacts on biodiversity

Source: De Silva and Soto (2009).

REFERENCES

Allison, E.H., Perry, A.L., Badjeck, M.C., Adger, W.N., Brown, K., Conway, D., Halls, A.S., Pilling, G.M., Reynolds, J.D., Andrew, N.L., & Dulvy, N.K. 2009. Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, 10(2): 173–196.

Badjeck, M-C., Mendo, J., Wolff, M. & Lange, H. 2009. Climate variability and the Peruvian scallop fishery: the role of formal institutions in resilience building. *Climate Change,* 94: 211–232.

Badjeck, M-C., Allison, E., Halls, A. & and Dulvy, N. 2010. Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy,* 34: 375–383.

Bell, J., Johnson, J. & Hobday, A. eds. 2011. *Vulnerability of tropical Pacific fisheries and aquaculture to climate change*. Secretariat of the Pacific Community, Noumea, New Caledonia (available at http://www.spc.int/climate-change/fisheries/assessment/e-book/).

Cheung, W.W.L., Lam, V.W.Y., Sarmiento, J.L., Kearney, K., Watson, R., Zeller, D. & Pauly, D. 2010. Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology*, 16(1): 24–35.

Cinner, J.E., McClanahan, T.R., Graham, N.A.J., Daw, T.M., Maina, J., Stead, S.M., Wamukota, A., Brown, K. & Bodin, Ö. 2012. Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. *Global Environmental Change*, 22(1): 12-20.

Daw, T., Adger, W.N., Brown, K. & Badjeck, M-C. 2009. Climate change and capture fisheries: potential impacts, adaptation and mitigation. *In* K. Cochrane, C. De Young, D. Soto & T. Bahri, eds. *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge*, pp. 107–150. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome, FAO. 212 p. (available at www.fao.org/docrep/012/i0994e/i0994e00.htm).

De Silva, S. & Soto, D. 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. *In* K. Cochrane, C. De Young, D. Soto & T. Bahri, eds. *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge,* pp. 151–212. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome, FAO. 212 pp. (available at www.fao.org/docrep/012/i0994e/i0994e00.htm).

FAO. 1995. *Conduct of conduct for responsible fisheries*. Rome. 41 p. (available at http://www.fao.org/docrep/005/v9878e/v9878e00.HTM).

FAO. 2003. *The ecosystem approach to fisheries.* FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. Rome. 112 p. (available at ftp://ftp.fao.org/docrep/fao/005/y4470e/y4470e00.pdf).

FAO. 2007. *An overview of the impact of the tsunami on selected coastal fisheries resources in Sri Lanka and Indonesia*. FAO RAP Publication (available at http://www.fao.org/docrep/010/ai000e/ai000e00.htm).

FAO. 2009a. *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge*, pp. 107–150. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome. 212 p. (available at www.fao.org/docrep/012/i0994e/i0994e00.htm).

FAO. 2009b. *Fisheries management. 2. The ecosystem approach to fisheries. 2.2 Human dimensions of the ecosystem approach to fisheries.* FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2, Add. 2. Rome. 88 p. (available at http://www.fao.org/docrep/012/i1146e/i1146e00.pdf).

FAO. 2009c. *Environmental impact assessment and monitoring in aquaculture.* FAO Fisheries and Aquaculture Technical Paper No. 527. Rome. 649 p. (available at http://www.fao.org/docrep/012/i0970e/i0970e00.htm).

FAO. 2010. *Aquaculture development. 4. Ecosystem approach to aquaculture*. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 4. Rome. 53 p. (available at http://www.fao.org/docrep/013/i1750e/i1750e.pdf).

IPCC. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. *IPCC Third Assessment Report* (available at http://www.grida.no/publications/other/ipcc_tar/).

Leonhard, S., Stenberg, C. & Stottrup, J. eds. 2011. Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities: Follow-up Seven Years after Construction. *DTU Aqua Report* No 246-2011 (available from http://www.aqua.dtu.dk/English.aspx).

Merino, G., Barange, M., Blanchard, J.L., Harle, J., Holmes, R., Allen, I., Allison, E.H., Badjeck, M.C., Dulvy, N.K., Holt, J., Jennings, S., Mullon, C. & Rodwell, L.D. 2012. Can marine fisheries and aquaculture meet fish demand from a growing human population in a changing climate? *Global Environmental Change*, 22(4): 795–806.

UNHCR (United Nations High Commissioner for Refugees). 2007. World Refugee Day: Addressing the Needs of African Refugees. Briefing and Hearing Before the Subcommittee on Africa and Global Health of the Committee on Foreign Affairs, House of Representatives – One Hundred and Tenth Congress. 20 June 2007.