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CLIMATE CHANGE AND AQUACULTURE: OPPORTUNITIES AND CHALLENGES FOR ADAPTATION AND MITIGATION

SUMMARY

Climate change is a potential threat to the sustainability of aquaculture development. The impact of such can occur as a result of both gradual warming and associated physical changes as well as from frequency, intensity and location of extreme events. It can take place in the context of other global socio-economic pressures on natural resources. Urgent adaptation measures are required in response to opportunities and threats to food and livelihood provision due to climatic variations. The present document briefly analyses the potential impacts of climate change on the aquaculture sector at the global and regional level. Overall, impacts on aquaculture are predicted to vary widely, depending on the current climatic zones of activity. Climate change impacts on aquaculture have both direct effects, e.g. through physical and physiological processes, and indirect effects, e.g. through variations in fish meal supplies and trade issues. Regarding contributions to greenhouse gas (GHG) emissions, aquaculture has limited relevance and the primary mitigation route for the sector lies in the reduction of energy consumption, through fuel and raw material use. Options to increase resilience and adaptability include adequate policies and practices with an ecosystem and cross sectoral perspective at regional, national, watershed scales as well as improved management practices at the farm scale.

BACKGROUND

1. Since the release of the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) in 2007¹, threats of climate change to human society and natural ecosystems have been given prominence. The Report contained far reaching conclusions on the current and projected trends in global warming and the likelihood that anthropogenic influences

¹ IPCC, 2007: CLIMATE CHANGE 2007: SYNTHESIS REPORT. CONTRIBUTION OF WORKING GROUPS I, II AND III TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [CORE WRITING TEAM, PACHAURI, R.K AND REISINGER, A. (EDS.)]. IPCC, GENEVA, SWITZERLAND, 104 PP.

were major drivers of climate change. Amongst the conclusions were: “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” and that “There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, global green house gas (GHG) emissions will continue to grow over the next few decades”

2. While the importance of fisheries and aquaculture is often understated, the implications of climate change on these sectors and coastal and riparian communities in general are difficult to ignore. Concurrently, fisheries and aquaculture do contribute, albeit to a limited extent, to GHG emissions, and present some opportunities for mitigation efforts.

3. Currently, aquaculture contributes nearly 50 percent of the global food fish supply (45 percent in 2007). This contribution is expected to grow over the coming decades. It is imperative that the aquaculture sector continues to produce food fish in the coming decades. If not, per caput consumption of fish will be reduced as the global population continues to grow. Climate change may hinder such expectations, yet it may also provide new opportunities for aquaculture.

4. The present document briefly analyses some of the potential climate change impacts on global and regional aquaculture. And in this regard summarizes information realized by the FAO Fisheries and Aquaculture Department in response to requests made by the Committee on Fisheries (COFI) and the COFI Sub-Committee on Aquaculture (COFI-AQ). This information, in future, will allow for a better understanding of climatic change impacts, thereby facilitating the formulation and provision of adaptation and mitigation options to members.

ACTIVITIES OF FAO AND THE FISHERIES AND AQUACULTURE DEPARTMENT (FI) ON CLIMATE CHANGE

(i) Expert Workshop on Climate Change Implications for Fisheries and Aquaculture

5. At its 27th Session COFI requested FAO to undertake a scoping study to identify the key issues on climate change and fisheries. The Committee further recommended that the study be partially financed and substantively supported by the FAO High-Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy. In response, the Fisheries and Aquaculture Department held an Expert Workshop on “Climate Change Implications for Fisheries and Aquaculture” in April 2008 in which three comprehensive technical reviews were prepared by leading authorities in the field (Cochrane et. al. 2009)². Conclusions and Recommendations of the Workshop Report³, relevant to both fisheries and aquaculture, are summarized in the document entitled “Options for decision makers” (De Silva and Soto, 2009)⁴.

(ii) High-Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy

6. The High-Level Conference on “World Food Security: The Challenges of Climate Change and Bioenergy” was held at FAO Headquarters from 3 to 5 June 2008. One hundred and

² COCHRANE, K.; DE YOUNG, C.; SOTO, D.; AND BAHRI, T. (EDS). CLIMATE CHANGE IMPLICATIONS FOR FISHERIES AND AQUACULTURE: OVERVIEW OF CURRENT SCIENTIFIC KNOWLEDGE. *FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER*. No. 530. ROME, FAO. 2009. 212p.

³ FAO, 2008. REPORT OF THE FAO EXPERT WORKSHOP ON CLIMATE CHANGE IMPLICATIONS FOR FISHERIES AND AQUACULTURE. ROME, ITALY, 7–9 APRIL 2008. FAO FISHERIES REPORT. No. 870. ROME, FAO. 2008. 32p.

⁴ DE SILVA, S.S. AND SOTO, D. 2009. CLIMATE CHANGE AND AQUACULTURE: POTENTIAL IMPACTS, ADAPTATION AND MITIGATION. IN K. COCHRANE, C. DE YOUNG, D. SOTO AND T. BAHRI (EDS). CLIMATE CHANGE IMPLICATIONS FOR FISHERIES AND AQUACULTURE: OVERVIEW OF CURRENT SCIENTIFIC KNOWLEDGE. *FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER*. No. 530. ROME, FAO. PP. 151-212.

[HTTP://WWW.FAO.ORG/FILEADMIN/USER_UPLOAD/FOODCLIMATE/PRESENTATIONS/FISH/OPTIONSEM7.PDF](http://www.fao.org/fileadmin/user_upload/foodclimate/presentations/fish/optionsEM7.pdf)

eighty-one member countries participated, including 42 Heads of State and Government, 100 Ministers and representatives from 60 non-governmental and civil society organizations. In preparation for the Conference a series of Expert Meetings was held including fisheries and aquaculture. Details of these meetings and the reports can be obtained from <http://www.fao.org/foodclimate/expert/en/>.

7. The Conference adopted the Declaration by acclamation asserting that “The current crisis has highlighted the fragility of the world’s food systems and their vulnerability to shocks. While there is an urgent need to address the consequences of soaring food prices, it is also vital to combine medium and long-term measures, such as the following: It is essential to address the fundamental question of how to increase the resilience of present food production systems to challenges posed by climate change. In this context, maintaining biodiversity is the key to sustaining future production performance. We urge governments to assign appropriate priority to the agriculture, forestry and fisheries sectors, in order to create opportunities to enable the world’s smallholder farmers and fishers, including indigenous people, in particular in vulnerable areas, to participate in, and benefit from financial mechanisms and investment flows to support climate change adaptation, mitigation and technology development, transfer and dissemination.”

(iii) Partnership to support the UNFCCC process and to better coordinate climate change adaptation and mitigation in fisheries and aquaculture

8. The Fisheries and Aquaculture Department is actively exploring options to increase its technical support to Members on climate change implications for fisheries and aquaculture, in cooperation with other relevant agencies. A key activity in this respect was the informal coordination meeting organized jointly with the World Bank and WorldFish Centre, held at FAO in Rome in March 2009. The aim of the meeting was to provide an opportunity for those international organizations and agencies leading initiatives regarding the threats of climate change to fisheries and aquaculture to discuss their work programmes and agree on a means to improve coordination and cooperation. The outcome of the meeting was a framework for a Global Programme on climate change adaptation and mitigation in fisheries and aquaculture and a partnership for climate change, Fisheries and Aquaculture (PaCFA).

9. The Global Partnership for Climate, Fisheries and Aquaculture (PaCFA), comprising 20 international organizations and sector bodies (http://www.climatefish.org/index_en.htm), was borne from a mutual desire to draw together potentially fragmented and redundant climate change activities through a multi-agency global programme of coordinated actions and the pressing need to raise the profile of fisheries and aquaculture in the United Nations Framework Convention on Climate Change (UNFCCC) negotiating process. Its goal is to support the process of the United Nations Framework Convention on Climate Change (UNFCCC) in response to the need for concerted action on fisheries, aquaculture and climate change. It lays the groundwork for a coordinated response from the fisheries and aquaculture sector to climate change, notably through a strategic approach to maintain or enhance the health and resilience of global oceans and waters, and strengthening the capacity of dependent people and communities, integrating these closely into broader development strategies.

10. The immediate aim of PaCFA was to highlight key issues to alert and inform decision makers and climate change negotiators at the [UNITED NATIONS CLIMATE CHANGE CONFERENCE](#) in Copenhagen in December 2009 (COP15). This partnership provided an important platform for discussion on the climate change issues in aquatic food production systems.

(iv) Field and normative activities

11. In addition to the ongoing field and normative activities, proposals have been submitted to donors to address the “Reduced vulnerability of fishing and fish farming communities to natural disasters” including species introductions, fish disease epizootics, and climate change. It is

intended to address both short and long-onset disasters, including climate change. It is expected that the collection of more detailed information from more sensitive areas and regions of the world will also improve the Fisheries and Aquaculture Department's ability to produce guidelines and specific policy options documents to assist climate change adaptation in fisheries and aquaculture. Additional proposals may be submitted in future, depending on requests from donor and recipient countries and the on-going priority given to climate change by the Committee on Fisheries (COFI) and the COFI Sub-Committee on Aquaculture (COFI-AQ). Current field and normative work, focusing on defining indicators of vulnerability for fisheries and aquaculture and pilot assessment activities, is being carried out under a Japanese Trust Fund project .

CLIMATE CHANGE AS AN EXTERNAL FORCING FACTOR: THE PHYSICAL EVIDENCE AND CONSEQUENCES FOR AQUACULTURE

12. Climate change is already affecting the seasonality of some biological processes, radically altering marine and freshwater food webs, with somewhat unpredictable consequences for aquaculture. Increased risks of species invasions and spreading of vector-borne diseases raise further concerns. Differential warming between land and oceans and polar and tropical regions will affect the intensity, frequency and seasonality of climate patterns (e.g. El Niño) and extreme events (e.g. floods, droughts, storms). It will also affect the stability of marine and freshwater resources relevant for aquaculture, affecting infrastructure and increasing human risk. Sea level rise, glacier melting, ocean acidification and changes in precipitation, groundwater and river flows will significantly affect coastal ecosystems, wetlands, rivers, lakes and estuaries, requiring adapting measures to exploit opportunities and minimize impacts on aquaculture systems and species.

13. Oceans are warming but this warming is not geographically homogeneous. There is evidence that inland waters are also warming, with differential impacts on river run off. However, current climate models are not yet sufficiently developed to resolve the effects of such changes in productivity of oceans and water bodies at finer geographical scales.

14. The global mean sea level has been rapidly rising, and the Atlantic, Gulf of Mexico, Mediterranean, Baltic Sea, small-island regions, Asian mega-deltas and other low-lying coastal urban areas are particularly at risk. Ocean acidification has decreased seawater pH by 0.1 units in the last 200 years and models predict a further reduction of 0.3-0.5 pH units over the next 100 years. The impacts of ocean acidification will be particularly severe for shell-borne organisms; it is unknown how it will affect the farming of bivalves. Climate change also affects inland ecosystems which include changes in sediment loads, water flows and physical-chemical consequences (hypoxia, stratification, and salinity changes), etc.

15. Freshwater resources have the potential to be strongly affected by climate change, including a decrease of between 10 and 30 percent of the average river runoff at mid-latitudes, and in the dry tropics by the mid-century, but increases of 10 - 40 percent at high latitudes in the wet tropics. In Africa, warming is very likely to be greater than the global annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics. Annual rainfall is likely to decrease in much of Mediterranean Africa and the northern Sahara, with a greater likelihood of decreasing rainfall as the Mediterranean coast is approached. The consequences of these processes are complex and will impact the availability of freshwater and community composition, production and seasonality processes in aquatic ecosystems in general. This will put additional pressure on inland fish and land-based, water intensive, food production systems including aquaculture, particularly in developing countries (Cochrane *et. al.* 2009).

FORESEEN IMPACTS OF AQUACULTURE

16. Climate change impacts on aquaculture have both direct (e.g. through physical and physiological processes) and indirect (e.g. through variations in fish meal supplies and trade issues) effects.

17. In summary; the known potentially negative effects, as outlined in IPCC 2007 and Cochrane *et. al.* 2009, include:

- stress to farmed organisms due to increased temperature, salinity and oxygen demands. Such stress will affect physiological processes and food requirements therefore local conditions in traditional rearing areas could become unsuitable for many traditional species. Changes on ocean physical conditions will also affect availability of seeds for aquaculture;
- increasing restrictions to inland aquaculture due to diminishing supplies and availability of freshwater;
- extreme weather conditions (hurricanes, changes in Monsoonal rain patterns, droughts, flooding etc.) affecting aquaculture infrastructure, production, human lives and livelihoods; e.g. shrimp farming losses after hurricanes in Central America countries;
- sea level rise affecting current and future farming activities (e.g. freshwater) e.g. the growth of freshwater catfish in the Mekong Delta;
- increased frequency of diseases and toxic events. Many fish diseases are susceptible to climate change. Temperature and rainfall are critical ecological factors for the distribution of many pathogens. Stressed fish due to climatic factors are also more susceptible to diseases;
- warming can enhance the expansion ability of some exotic species (e.g. tilapia) but could also reduce the expansion of others (salmon);
- uncertain supplies of fishmeal/oil from capture fisheries. Climate change predictions for many pelagic species such as those producing fish meal and fish oil indicate increasing variability and potential scarcity. This will negatively affect more carnivorous species, and
- increasing acidity in the oceans may affect the farming of molluscs (shell formation).

18. Potentially positive climate change impacts (and opportunities within mitigation scenarios) for aquaculture include:

- increased food conversion efficiencies and growth rates in warmer waters for those species that are able to adapt;
- increased growth rates due to more productive waters (increased primary production) and more available food for herbivorous and filter feeder life stages and species;
- increased length of the growing season;
- poleward expansions of habitat range due to decrease in ice and increased temperatures;
- aquaculture can offer alternative livelihoods to other more affected sectors, such as coastal agriculture under sea rise effects and to fisheries if resources are depleted; and
- the aquaculture of filter feeder (e.g. mussels) and extractive species (seaweeds) could gain momentum and be suitable for premium assistance and subsidies due to their limited carbon foot print, zero freshwater consumption, their mitigation potential and ecosystem services.

19. The aforementioned negative and positive effects are greatly dependent on regional, sub-regional, national and local contexts. It is impossible to make global generalizations.

20. Aquaculture is not practised evenly across the globe and in order to evaluate the potential impacts of climate change it is necessary to understand (i) the climatic regimes where aquaculture

takes place *vis-à-vis* tropical, subtropical and temperate; (ii) the environments where aquaculture is practiced *vis-à-vis* marine, fresh and brackish waters; and (iii) the geographic division by continent where they are practiced. Aquaculture is geographically concentrated in the Asian region and is predominant in tropical and subtropical climatic regions; climatic changes affecting such regions could have a greater impact on the global sector. On the other hand some climate change impacts, e.g. increasing water temperatures, will impact to a greater degree the temperate zones while sea level rise will have larger impacts on island states and lowland coastal zones. Hence, the aquaculture sector in different regions and countries face different risks.

21. The more negative impacts are likely to be on aquaculture operations in temperate regions, viz: the impinging rate of growth of cultured, cold water species, resulting from exceeding the optimal temperature ranges for body function, and increasing the potential hazards of diseases through the increase of virulence resulting from increased temperatures. The latter has a combined effect of expanding range of pathogens and more sensibility to disease on stressed individuals.

22. In tropical and subtropical regions, where aquaculture activities predominate, increase in water temperature particularly freshwater would bring about the opposite, resulting in increased production. In addition, sea level rise will positively impact aquaculture in many instances and may possibly provide alternative livelihood means for many practitioners of terrestrial agriculture in deltaic areas. Most importantly, aquaculture frequently offers a less energy consuming food production alternative in comparison with others and should be recognised as such.

AQUACULTURE INCIDENCE ON GREEN HOUSE GASES (GHG) AND THE POTENTIAL FOR MITIGATION WITHIN THE SECTOR

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

24. The green house gas contributions of fisheries and aquaculture and related supply chain features are small compared to other sectors but, nevertheless, can be improved with already available identifiable measures. In many instances, climate change mitigation could be complementary to and reinforce existing efforts to improve aquaculture sustainability. Aquaculture's main contribution to GHG emission takes place, indirectly, in the consumption of fishmeal produced in fisheries which, in turn, may have relevant carbon emission in the fishing process and transport of raw material.

25. Technological innovations could reduce reliance on fish meal, efficient production and post-harvest and distribution systems. There may also be valuable opportunity for interactions in the sector with regard to environmental services (e.g. maintaining the quality and function of sensitive habitats, coastal margins, inland watersheds), and potential carbon sequestration and other nutrient management options (e.g. through seaweeds), these, however, will need further research and development (R&D). The sustainable use of genetic diversity, including through biotechnologies, could have particular efficiency impacts, e.g. through widening production scope of low-impact aquaculture species, or making agricultural crop materials or waste products usable for growing carnivorous aquatic species. This would need to be evaluated based on wider social, ecological and political criteria. Mitigation R&D expenditure will need to be justified clearly by comparison with other sectors whose impacts could be much greater, but policy influence could be used to support more efficient practices using available approaches.

26. Possible negative impacts of mitigation on food security and livelihoods would have to be better understood and justified but these will need further research and development (R&D).

27. Aquaculture can provide good quality protein with much lower carbon foot print than other comparable terrestrial animal production systems. Such advantages must be explored further through life cycle analysis or other comparative methods, not only to improve sustainability but also the image of aquaculture and increasing consumer confidence. Some aquaculture systems such as the mariculture of filter-feeders and seaweeds have minimum or no incidence on GHG emissions. On the contrary they can provide ecosystem services (such as filtering and absorbing excess nutrients in the water) that should be also valued (FAO, 2008)⁵.

28. Life cycle assessment studies indicate that any farmed aquatic organism relying mainly on fish meal and fish oil for feeds is costly in terms of energy⁶. Efforts must be made to reduce the use of these feed components. However, such efforts will invariably have major social and economic impacts on the producing countries and on countries that rely more on carnivorous high value species when there is a need to strike a balance.

ADAPTING TO CHANGE

29. Although resource-dependent activities and the people involved, particularly coastal communities, have adapted to change throughout history, projected climate change poses multiple additional risks to the aquaculture sector that might limit the effectiveness of past adaptive strategies.

30. Location specific adaptation strategies with both short-term (e.g. increased frequency of severe events) and long-term (e.g. reduced freshwater supply) impacts need to be considered. All three levels of adaptation (community, national and regional) will clearly require and benefit from stronger capacity building, through rising awareness of climate change impacts on the sector and general education and targeted initiatives in and outside the sector.

31. Options to increase resilience and adaptability through improved aquaculture management include the adoption, as a standard practice, of adaptive and precautionary management. An ecosystem approach to aquaculture (EAA)⁷ should be adopted to increase the resilience of aquatic resources, aquaculture production systems and the dependent communities.

32. Most relevant management measures at the farm scale include: i) proper site selection and considerations to carrying capacity aspects and biosecurity in general and ii) Better management practices (BMPs) can be adopted by individual farmers and clusters of farmers. Practices including proper feeding and optimization of feed conversion factors can improve both CC adaptation and mitigation aspects. Health management of farmed species and prevention of escapees are also relevant measures considering that more stressful conditions for farmed organisms enhance their vulnerability to diseases. The likelihood of disease spread can be minimized by increasing the minimum distance between farms and by implementing tight biosecurity programmes for aquaculture clusters or zones.

33. The EAA at the watershed scale is especially relevant for adaptation under climate change. A proper aquaculture zoning mechanism, biosecurity frameworks, risk analysis and strategic environmental assessments (FAO, 2009) that take in account the added effects of many

⁵ FAO. 2008. REPORT OF THE FAO EXPERT WORKSHOP ON CLIMATE CHANGE IMPLICATIONS FOR FISHERIES AND AQUACULTURE. ROME, ITALY, 7–9 APRIL 2008. FAO FISHERIES REPORT No. 870

⁶ DE SILVA, S.S. AND SOTO, D. 2009. CLIMATE CHANGE AND AQUACULTURE: POTENTIAL IMPACTS, ADAPTATION AND MITIGATION. IN K. COCHRANE, C. DE YOUNG, D. SOTO AND T. BAHRI (EDS). CLIMATE CHANGE IMPLICATIONS FOR FISHERIES AND AQUACULTURE: OVERVIEW OF CURRENT SCIENTIFIC KNOWLEDGE. *FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER*. No. 530. ROME, FAO. PP. 151-212.

⁷ SOTO, D.; AGUILAR-MANJARREZ, J.; HISHAMUNDA, N. (EDS). 2008. BUILDING AN ECOSYSTEM APPROACH TO AQUACULTURE. FAO/UNIVERSITAT DE LES ILLES BALEARS, EXPERT WORKSHOP. 7–11 MAY 2007, PALMA DE MALLORCA, SPAIN. *FAO FISHERIES AND AQUACULTURE PROCEEDINGS*. No. 14. ROME, FAO. 2008. 221P. [HTTP://WWW.FAO.ORG/DOCREP/011/I0339E/I0339E00.HTM](http://www.fao.org/docrep/011/i0339e/i0339e00.htm)

farms and other activities are most relevant in order to better approach potential threats such as new diseases, invasive species, eutrophication related problems that can be exacerbated by climate change (e.g. increased water temperature and salinity).

34. The EAA emphasizes the need to integrate aquaculture with other sectors (e.g. fisheries, agriculture, and urban development) that share and affect common resources (land, water, feeds, etc.) The implementation of EAA at the water body scale is one of the most relevant adaptations to climate change. Geographical responsibility of aquaculture development authorities (i.e. administrative boundaries) often do not include watershed boundaries and this is a particular challenge as 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. Adaptations by other sectors will have an impact on aquaculture (e.g. irrigation infrastructure, dams, fertilizer use runoff), and will require carefully considered trade-offs or compromises.

35. Alternatively, aquaculture can provide adaptation for coastal agricultural communities that may face salinization effects due to rising sea levels.

36. In the Near East and North Africa, where freshwater resources are becoming increasingly limited, cage culture systems (non consumptive water use) and mariculture should be considered, as both options have less dependency from freshwater compared to land-based food production systems.

37. Aquaculture systems, which are less or non-reliant on fishmeal and fish oil inputs (e.g. herbivorous fish, bivalves and macroalgae), have better scope for expansion than production systems dependent on capture fisheries commodities.

38. Adaptation options also encompass diversification of livelihoods and promotion of aquaculture crop insurance in the face of potentially reduced or more variable yields.

39. Integrated aquaculture can offer benefits including bioremediation, such as in the case of integrated multitrophic aquaculture. Reducing risks is another advantage and a profitable aspect of farming multiple species⁸. A diversified product portfolio will increase the resilience of the operation, for instance, when facing changing prices for one of the farmed species or the loss of a crop for example due to climate change (a disease, physiological stress). However, some of the normative elements that are necessary to enhance this practice are not there yet, e.g. appropriate legal frameworks.

40. With the rise of more frequent and severe weather conditions, strategies for reducing vulnerabilities of aquaculture have to address measures including: climate related risk assessment of current and future aquaculture zones, capacity building on improved forecasting; early warning systems and improved safety at sea.

41. More generally, adaptation strategies should promote disaster risk management, including disaster preparedness within integrated coastal area management (as in EAA). National climate change adaptation and food security policies and programmes would need to fully integrate into 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.

⁸ 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.

OPTIONS FOR ENABLING ADAPTATION AND OPPORTUNITIES

42. Appropriate international, regional and national policies are required to minimize negative impacts of climate change, improve mitigation and prevention, and maintain and build adaptive capacity to climate change. These must include:

- **Developing the knowledge base:** In the future, planning for uncertainty will need to take into account unforeseen events, such as the increasing frequency of extreme weather conditions. Improved knowledge and how to address these matters, will be valuable in a number of areas e.g. projections of future fish production levels, detailed impact predictions on specific aquaculture systems, improved tools for decision-making under uncertainty, and improved knowledge of who is or will be vulnerable to climate change and food security impacts.
- **Policy, legal and implementation frameworks:** Addressing the potential complexities of climate change interactions and their possible impacts requires mainstreaming of cross sectoral responses into governance frameworks. Action plans at the national level can have as a basis the Code of Conduct for Responsible Fisheries (CCRF) as well as appropriately linked policy and legal frameworks and management plans. Links will be required among national climate change adaptation policies and programmes as well as cross - sectoral policy frameworks such as those for food security, poverty reduction, emergency preparedness and others. The potential for spatial displacement of aquatic resources and people as a result of climate change impacts will require existing regional structures and processes to be strengthened and rendered more focused. Internationally, sectoral trade and competition issues are also likely to be impacted by climate change.
- **Capacity building:** action planning in response to climate change involves not only the technically concerned agencies, such as departments responsible for aquaculture, agriculture, interior affairs, science and education, but also those for national development planning and finance. These institutions, as well as community or political representatives at sub-national and national level, should also be identified to receive targeted information and capacity building. Partnerships would also need to be strengthened among the public, private, civil society and NGO sectors.
- **Enabling financial mechanisms:** The full potential of existing financial mechanisms, such as insurance, at national and international levels will be needed to tackle the issue of climate change. This will be particularly a challenge for small aquaculture farmers and the facilitation of their organization in clusters and associations could be a relevant approach. Innovative approaches may also be needed to target financial instruments and to create effective incentives and disincentives. The public sector will have an important role in leveraging and integrating private sector investment, interacting through market mechanisms to meet sectoral aims for climate change response and food security. Many of these approaches are new and will need to be tested in the sector.

SUGGESTED ACTION BY THE SUB-COMMITTEE

43. The Sub-Committee is invited to:
- revise, as appropriate, the ideas explored in this paper and identify additional actions which could help Member countries to better face the challenges and opportunities imposed by climate change;
 - provide guidance on the priority actions to be taken by the Secretariat and the way forward on this subject in general.