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Global aquaculture and its role in sustainable development

Rohana Subasinghe, Doris Soto and Jiansan Jia

Aquaculture Management and Conservation Service, Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, Rome, Italy

Correspondence
Rohana Subasinghe, Room F506, Aquaculture Management and Conservation Service, Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00153 Rome, Italy.
Email: rohana.subasinghe@fao.org

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Abstract

Aquaculture is the fastest growing food-producing sector in the world. It is developing, expanding and intensifying in almost all regions of the world. The global population is increasing, thus, the demand for aquatic food products is also increasing. Production from capture fisheries has levelled off and most of the main fishing areas have reached their maximum potential. Sustaining fish supplies from capture fisheries will, therefore, not be able to meet the growing global demand for aquatic food and aquaculture is considered to be an opportunity to bridge the supply and demand gap of aquatic food in most regions of the world. However, in our efforts to achieve this potential, the sector will face significant challenges. Key development trends indicate that the sector continues to intensify and diversify and is continuing to use new species and modify its systems and practices. Markets, trade and consumption preferences strongly influence the growth of the sector, with clear demands for the production of safe and quality products. As a consequence, increasing emphasis is placed on enhanced enforcement of regulation and better governance of the sector. It is increasingly realized that sustainable development and responsible production of aquaculture, in the long run, cannot be achieved without the full participation of the producers in the decision-making and regulation process, which has led to efforts to empower farmers and their associations and move toward increasing self-regulation. These factors are all contributing to an improvement in the management of the sector, typically through the promotion of 'better management' practices of producers. This review discusses the role of aquaculture, as at large a small-scale farmer driven production sector, in the quest for sustainable development, reducing poverty and improving food security on a global scale.

Key words: aquaculture, fish, fishfarming, mariculture, seafood, sustainability.

Introduction

Global production of fish from aquaculture has grown rapidly over the past four decades, contributing significant quantities to the world's supply of fish for human consumption. Aquaculture now accounts for almost half (45%) of the world's food fish (note that 'food fish' or simply 'fish' in this document refers to production of aquatic animals [fish, crustaceans, molluscs, echinoderms, amphibians]). Aquatic plants are considered separately. With its continued growth, it is expected that aquaculture will, in the near future, produce more fish for direct human consumption than capture fisheries.

Aquaculture, which started as primarily an Asian freshwater food production system, has now spread to all continents, encompassing all aquatic environments and using a range of aquatic species. From an activity that was principally small scale, non-commercial and family based, aquaculture now includes large-scale commercial and industrial production of high-value species that are traded at national, regional and international levels. Although production remains predominantly Asian and is still

largely based on small-scale operations, there is a wide consensus that aquaculture has the potential to meet the growing global demand for nutritious food fish and to contribute to the growth of national economies, while supporting the sustainable livelihoods of many communities (FAO 2006a).

Production trends

World aquaculture has grown tremendously over the past 50 years from a production of less than one million tonnes in the early 1950s to 48.1 million tonnes in 2005 (all production data provided in this document are based on 2005 production statistics given in FAO FishStat+ 2007 database); an average annual growth rate of 8.8% (Fig. 1). Current production had a farm-gate value of US$70.3 billion, increasing significantly in value as farmed products move along the market chain to consumers. Of this production, 32.4 million tonnes (or 67.3%) was produced in the People's Republic of China (hereafter referred to as China) and 22.3% from the rest of the Asia–Pacific region (Table 1). Western Europe contributed 4.2% with 2.0 million tonnes (valued at US$6.2 billion), while Central and Eastern Europe contributed 270 000 tonnes or 0.6%. Latin America and the Caribbean and North America contributed 2.9 and 1.3%, respectively. Finally, production from the Near East and North Africa and sub-Saharan Africa accounted for 1.2 and 0.2%, respectively, of the global total for 2005 (Table 2). In addition to fish production, aquaculture activities in 2005 produced 14.8 million tonnes of aquatic plants worth US$7.1 billion. The vast majority of aquatic plant production (99.8%) came from the Asia–Pacific. The projection of future food supply from aquaculture in Figure 1 might be conservative and it is possible that aquaculture will reach 50% of the total supply in the next biennium.

Production within each region is diverse. In the Asia–Pacific, aquaculture production from South Asia, China and most of South-East Asia consists of cyprinids, whereas production from the rest of East Asia consists of high-value marine fish. In global terms, 97.5% of cyprinids, 88.6% of penaeids and 95.0% of oysters come from the Asia–Pacific region. Meanwhile, 53.1% of the world's farmed salmonids come mainly from the northern part of Western Europe (FAO 2007a) and almost 45% comes from South America. Carp, however, dominate in Central and Eastern Europe, both in quantity and in value (FAO 2007b).

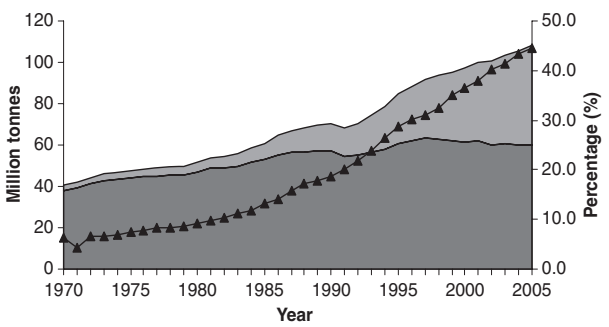

Figure 1 Contribution to food-fish supply. ▭, Aquaculture; ▭, capture; –▲–, AQ share.

Table 1 Top 20 food fish aquaculture producing countries

Country	Production (1000 tonnes)	Percentage	Cumulative percentage
China	32 414	67.3	67.3
India	2838	5.9	73.2
Viet Nam	1437	3.0	76.2
Indonesia	1197	2.5	78.7
Thailand	1144	2.4	81.1
Bangladesh	882	1.8	82.9
Japan	746	1.5	84.4
Chile	698	1.5	85.9
Norway	657	1.4	87.3
Philippines	557	1.2	88.4
Egypt	540	1.1	89.5
Myanmar	475	1.0	90.5
United States of America	472	1.0	91.5
Republic of Korea	436	0.9	92.4
Taiwan, Prov. of China	305	0.6	93.0
France	258	0.5	93.6
Brazil	258	0.5	94.1
Spain	222	0.5	94.6
Italy	181	0.4	94.9
Malaysia	176	0.4	95.3
Rest of the world	2257	4.7	100.0
World total	48 150	100.0	

In North America, channel catfish and salmon are the top aquaculture species (FAO 2006d). In Latin America and in the Caribbean region, over the past decade, salmonids have overtaken shrimp as the top aquaculture species group. This trend was partly influenced by disease outbreaks in major shrimp-producing countries in Latin America and by rapid growth in salmon production in Chile (FAO 2006c).

Although sub-Saharan Africa has significant water and land resources, it has, to date, been only a minor player in aquaculture development for a variety of reasons (FAO 2006e). Although some improvements are taking place, the situation in sub-Saharan Africa highlights that economics, human demand and interest, institutional aspects and a wide variety of other factors unrelated to the resource potential, are all contributing to this situation. Near East and North African aquaculture is confined to a few countries; in particular, Egypt dominates the production of tilapia, making a significant contribution to the regional production (FAO 2006f).

Table 2 Aquaculture production (volume and value) in 2005 in different regions of the world

Country/region	Production volume (million tonnes)	Production volume (%)	Production value (billion US$)	Production value (%)	Value (US$)/tonne
China†	32.4	67.3	35.99	51.2	1111
Rest of the Asia–Pacific	10.7	22.3	20.6	29.3	1925
Western Europe	2	4.2	5.42	7.72	2710
Latin American and the Caribbean	1.4	2.9	5.24	7.47	3743
North America	0.6	1.3	1.3	1.86	2167
Near East and North Africa	0.6	1.2	0.83	1.19	1383
Central and Eastern Europe	0.3	0.6	0.67	0.91	2233
Sub-Saharan Africa	0.1	0.2	0.25	0.36	2500
World total	48.1	100	70.3	100	1462

†For easy reference, the Asia–Pacific region has been separated into China and the rest of the Asia–Pacific.

The value of aquaculture production also varies significantly among regions (Table 2), and in some cases it can be much greater than the value of fisheries exports, for example, in Latin America aquaculture represents only 7% of the total fish production, but this is 57% of the total export value of fish products (FAO 2007d). This difference among regions is influenced by the value of certain commodity products, such as salmon and shrimp, which are mainly produced for export markets.

Contribution to food security, nutritional well-being, poverty reduction and economic growth

Aquaculture plays an important role in global efforts to eliminate hunger and malnutrition by supplying fish and other aquatic products rich in protein, essential fatty acids, vitamins and minerals. Aquaculture can also make significant contributions to development by improving incomes, providing employment opportunities and increasing the returns on resource use. According to FAO figures, aquaculture directly created 12 million full-time employment positions in Asia in 2004 (FAO 2006b). It significantly contributes to the national gross domestic product in many developing countries in Asia and Latin America (FAO 2006c). With appropriate management, the sector appears ready to meet the expected shortfalls in fish supplies for the coming decades and to improve global food security.

The availability of sufficient and good-quality food, access to this food by households and individuals, and its utilization for nutritious diets and good health are interdependent dimensions of food security. With respect to food availability, aquaculture contributes to the quantity of food through the supply of aquatic products from domestic farming and through the supply of food purchased using foreign exchanges. Aquaculture contributes to food quality by providing nutritious and energetic aquatic food products that are high in protein, essential fatty acids, vitamins and minerals. The health benefits associated with the consumption of fish products are particularly important for the prevention of heart-related diseases and for many vulnerable groups, such as pregnant and lactating women, infants and pre-school children. In this respect, aquaculture contributes to nutritional well-being. Understanding the benefits of fish products has triggered a substantial increase in consumption, particularly in developed nations, but not so much in developing countries. By 2002 fish (fisheries and aquaculture) products contributed 12% of the total protein for human consumption (FAO 2006g), although there are no detailed global statistics on the provision of other essential minerals and components.

The availability of food is a necessary, but not sufficient, condition for food security. Affordability is a major aspect of food access. By providing farmers with revenues obtained through the sale of their produce and by creating employment, aquaculture enhances a household's disposable income and its ability to purchase food. Increasing the availability of aquatic products to domestic markets can lower the price of these products, thereby making them affordable and more accessible to local consumers. Beyond individuals and households, at a macroeconomic level, aquaculture can also contribute to a country's economic performance and growth by generating profits and producing tax and export revenues. Good infrastructure and investments in human capital will improve the productivity of labour and capital, benefiting local businesses and enhancing the development of rural communities.

With existing resources and technological advances, food fish production from aquaculture can be further expanded in a more sustainable manner. This is only possible if the sector's socio-economic benefits accrue to a large social spectrum. Thus, the main challenge for policy makers and development agents is to create an 'enabling

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environment' for the aquaculture sector to maintain its growth, while meeting societal needs and preserving the natural resource base it needs. This enabling environment is multi-faceted and requires significant political will, sustained policy, public sector support and investment.

Addressing environmental and social issues and other risks within the sector

The environmental impacts of aquaculture development have received a high degree of attention over the past two decades, typically in cases where societal benefits were negatively affected by the consequences of unregulated aquaculture development. This attention is likely to become more pronounced in the coming decades, and will be constantly triggered by the increasing demand for products and services in a situation of increasing competition for land and water with other sectors/users and the diminishing feed resources for aquaculture. Such a scenario could also be enhanced by climatic change of varying degrees among regions (Handisyde *et al.* 2007).

With weak or improper regulations for the allocation and use of natural resources, there is always a tendency for conflicts to emerge between resource users. Invariably, less influential and disadvantaged stakeholders are denied access to these resources. Unregulated or improperly regulated aquaculture development also results in a high discounting rate on the use of natural resources and, therefore, encourages practices that exploit these resources beyond their carrying capacity.

As a result of strong public scrutiny on the environmental impacts of some forms of inconsiderate aquaculture development, starting approximately 10 years ago and gathering considerable momentum over the past 5 years, significant progress in addressing many of the key concerns in the environmental management of aquaculture has been made. This public pressure and continued commercial necessity have led the aquaculture sector to make great efforts to reduce and mitigate its environmental impacts and led governments to increasingly recognize that aquaculture, when well planned and well managed, can yield broad societal benefits without concomitant environmental degradation.

Indeed, it is now increasingly recognized that aquaculture can make a positive contribution (e.g. mitigation) to the environment by helping to reduce the negative impacts of other industries and activities (FAO 2006a). There are aquaculture systems that contribute to environmental rehabilitation or mitigate the impacts of effluents from other agricultural and even industrial operations. Well known are the integrated farming systems, such as rice-fish farming and fish farming in irrigated systems and the rehabilitation of endangered populations through stocking. The use of mollusc culture to improve carbon sequestering and seaweed culture in coastal areas to reduce aquatic nutrient loadings are also good examples of where aquaculture practices can serve as environmental sentinels, while at the same time contributing to socio-economic development.

Despite recent progress, there is no room for complacency. Continuing improvements, interventions and investments are required to ensure a higher degree of environmental sustainability and economic viability in the sector as pressures on the natural resource base and public awareness of environmental issues are reaching unprecedented levels. An ecosystem approach to aquaculture development can help reconcile the human and environmental objectives of sustainable development.

Aquaculture does not take place in isolation and in most cases it is not the only human activity in any given ecosystem, and it is possible that this food sector leads to smaller impacts on water bodies than other human activities (e.g. agriculture and industry). Although aquaculture has attracted much attention with regard to its potential environmental impacts we often forget that most terrestrial food-producing systems have been achieved after drastically transforming landscapes; however, historically society has grown used to this while aquaculture is a rather new development worldwide.

Because producing food for human needs (particularly intensive production) always has an environmental cost, these costs must be internalized in the accountings of the production process. It is also important to consider that aquaculture might be less costly than other protein products and a comparative evaluation of the environmental costs could be useful for making decisions on development options and improving management (Bartley *et al.* 2007).

Aquaculture needs an enabling policy environment to grow in a sustainable manner and to be integrated into the agro-ecosystems (when appropriate) or to other coastal zone uses, while minimizing conflict occurrence. In addition, the interactions between aquaculture and the larger system, in particular, the influence of the surrounding natural and social environment on aquaculture practices and results must also be taken into consideration. An ecosystem approach for aquaculture is a strategic approach to the development and management of the sector that aims to integrate aquaculture into the wider ecosystem, such that it is equitable and promotes the sustainability of interlinked social–ecological systems (Soto *et al.* 2008). Therefore, ecological, social and economic issues must be addressed at the proper scales: the farm, the watershed (e.g. containing clusters of aquaculture farms in interaction with other sectors) and the global market scale. The two latter scales often require policies and agreements beyond political boundaries (e.g. between countries or regions).

Coping with globalization, food safety, trade and markets

In 2005, approximately 40% (live weight equivalent) of world food fish production was internationally traded, with a value of US$78.4 billion. New markets are emerging worldwide. As high-value species are increasingly exported (intra-regionally or inter-regionally) and low-value products are imported, a particular trend in Asia, where, for example, shrimp are exported and canned pilchards are imported, there is a clear need by aquaculture farmers to improve the quality and safety of their products to gain a wider access to the export markets (FAO 2007c). However, with the more stringent requirements of export markets, small-scale farmers are facing difficulties in producing for export. As these farmers strive to meet export consumer requirements, they might become uncompetitive. This lack of competitiveness could drive them out of the sector. Empowering small farmers to become competitive in the global trade is becoming urgent and, perhaps, a significant corporate social responsibility.

Through trade and market access, globalization is increasingly playing an important role in aquaculture development. Its requirements are twofold: (i) strengthening of national, inter-provincial or inter-state, as well as regional and international, biosecurity and food safety measures; and (ii) enhancing ability, through training, legislation, codes of practice, certification, traceability schemes of governments and producers, to comply with trade and market access requirements for safe and quality products. These requirements are creating a considerable drive for importing and exporting countries to collectively harmonize standards and protocols and to address issues of certification of products and processors.

Certification in aquaculture can have positive effects by spurring new competitive advantages and investments, but it can also disguise underlying intentions to protect domestic industries and restrict market access. Compliance for some certification requirements could be costly and difficult for small farmers. As certification programmes proliferate, questions will be raised about which certification programmes best serve consumer protection, the environment, the public and the producers. Addressing these issues requires the promotion of harmonization and equivalence in the certification schemes and simplified compliance procedures.

As a consequence, there is a need for policy makers to emphasize these aspects when improving the governance of the sector. They must be aware that policies can be much more effective if producers participate in the decision making and regulation processes. Such recognition has already led many governments to build national capacities to assist producers and processors in complying with mandatory food safety regulations, while empowering farmers and their associations to move toward greater self-regulation. This move is contributing to an improvement in the management of the sector at the farm level, typically through the promotion of 'better management' practices and 'codes of practice' in well-organized associated producers.

The challenge of good governance

Changing resource availability, the regulatory environment, economics and increasing demand for fish and fishery products are forcing the aquaculture sector to intensify. Of these factors, the declining availability of suitable locations and constraints imposed by competition for water and increased regulation on discharges and abstraction appear to be the main driving forces.

In addition to calling for intensification, these constraints create opportunities elsewhere. For example, there is an increasing trend towards sea farming, with many countries experimenting with offshore and open-ocean aquaculture. The challenge is for policy makers to properly regulate the sector to ensure its orderly development and to discourage high discount rates on the use of natural resources and, thus, their exploitation beyond carrying capacity, while ensuring maximum benefits to society.

One of the prerequisites enabling aquaculture to make a contribution to sustainable development lies with a government's commitment to providing appropriate support to the sector. This commitment is expressed in the form of clear articulation of policies, plans and strategies and the availability of adequate funding and capacity building for their implementation. One of the main challenges is to avoid a trend seen across the agricultural sector where such commitment falters because of shifting government development priorities. The organization of government institutions is also relevant; in some cases the aquaculture sector is managed under fisheries institutions and in other cases under agriculture and food production institutions. Such organization must respond to the actual conditions and physical areas used by the aquaculture sector as well as to the orientation of the sector (e.g. production is for local markets or exports), and should promote the integration of aquaculture to other sectors/users of the coastal zones.

Although a government's commitment is necessary for aquaculture development, it is not sufficient to ensure sustainability. The aquaculture sector needs to operate under sound macro-economic, institutional and legal frameworks. Most successful aquaculture is driven by private sector investments. Private investments are vulnerable to political and legal instabilities, albeit external to

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the sector, and these factors seriously affect institutional development and deter private entrepreneurs.

Increasing flow of information and networking

In recent years, with the rapid growth of the aquaculture sector, the demand for reliable and timely information on the status and trends of aquaculture has greatly increased along with the need to expand the implementation of new technologies and management approaches. The demand stems from the need to formulate and monitor sound policies and development plans, respond to the reporting requirements of international agreements and respond to public demand for transparency and accountability. There have been many attempts to improve the information base on aquaculture globally. In Asia, improvement of the information base has been made possible through more formal networking among countries and institutions (e.g. Network of Aquaculture Centres in the Asia–Pacific; http://www.enaca.org). There is a push to establish more of these networks in other parts of the world.

Many networks of producer associations and groups do exist and have contributed significantly to the sector development. From aquaculture self-help groups, including women's groups in poor villages in Asia, to the more formal regional and international associations with their headquarters in Europe and the United States of America, producer groups have increasingly been playing a major role in global aquaculture development.

Special consideration for Africa

As noted above, a counterpoint to the rapid development of global aquaculture is its limited development in sub-Saharan Africa. This is the only region where the per capita consumption of fish has dropped, a trend we can ill afford to see continue or worsen, particularly when the decline in fish consumption has not been offset by an increase in the consumption of other animal proteins. Sub-Saharan Africa is also the only region where the contribution to the world aquaculture output remains below 1% (Table 2). There is a strong belief that Africa has the full resource potential for aquaculture growth. Our experience shows that aquaculture is slowly finding its niche in many countries in Africa, particularly cage aquaculture. Commercial cage culture is currently developing in Ghana, Kenya, Malawi, Uganda, Zambia and Zimbabwe, with variable but slowly increasing success (Blow & Leonard 2007). Despite these recent developments, the overall contribution could be improved considerably, making Africa a high-priority region for aquaculture development.

Therefore, there is a need for development agents and institutions to join hands to ensure that aquaculture and fish production in sub-Saharan Africa becomes part of the overall development process for the continent. Most countries in sub-Saharan Africa have limited resources to deliver quality public goods and services and many have a private sector (albeit under-developed) that could operate in its stead. Thus, there is a need for renewed and long-term focussed assistance to Africa's aquaculture sector, with a novel approach for development, making public–private partnerships possible, which builds on lessons learned from past mistakes and capitalizes on the emerging potential of the private sector. In addition, experiences in other regions and inter-regional cooperation can be most useful for this purpose. Relevant current initiatives involve international cooperation, benefiting several countries, to produce genetically improved tilapia seed, one of the bottlenecks to aquaculture growth in Africa, together with the production of quality feeds.

Future prospects

The aquaculture sector is expected to contribute more effectively to global food security, nutritional well-being, poverty reduction and economic development by producing, with minimum impact on the environment and maximum benefit to society, 85 million tonnes of aquatic food by 2030, an increase of 37 million tonnes over the level recorded in 2005.

Identifiable trends in the development of the aquaculture sector are: (i) continuing intensification of aquaculture production; (ii) continuing diversification of the species used; (iii) continuing diversification of production systems and practices; (iv) increasing influence of markets, trade and consumers; (v) enhancing regulation and improving governance of the sector; and (vi) increasing attention on better management of the sector. These trends do not apply equally to all regions because of intra-regional and inter-regional differences in the stages of aquaculture development, but they do reflect the behaviour of the sector in those countries where aquaculture is well established. It is possible that in some regions and countries mariculture will develop at a faster rate as freshwater aquaculture might encounter more restrictions owing to increasing competition for water resources, particularly in a global warming scenario. In addition, offshore mariculture is an option that avoids conflicting uses of coastal areas, while also avoiding and minimizing pollution of coastal environments. However, offshore farming possesses great challenges with regard to technological and economic investments that might restrict and slow down the use of this technology in certain regions and countries, at least initially.

Even with the expected increases in aquaculture production, the question remains whether the industry can grow fast and sustainably enough to meet the projected levels necessary to maintain fish supply while preserving the natural resource base required for it to thrive. Assuming a sustained demand for fish (i.e. the world is prepared to pay for fish as a desirable food product), there are plenty of unexplored opportunities that could enable aquaculture to significantly contribute to a country's sustainable development. These include: (i) the application of innovative capacity enhancement programmes by producers; (ii) the search for new production systems and technologies; and (iii) the development of new aquatic products and markets and integration into the eco-tourism, agriculture and fisheries sectors. Although some of the areas are not strictly unexplored, considerable support is required to realize their full potential.

Although there are indications that aquaculture can cover the gap between the expected demand and food fish supply from capture fisheries, there are constraints that could dampen or even stall production increases, thereby preventing the aquaculture supply from meeting the expected demand in decades to come. Aquaculture will fail to contribute further to sustainable development globally in general, and in fish farming nations in particular, should the supply decrease or stall.

There is a concern that the available marine resources (e.g. fishmeal and fish oil) might not be sufficient to meet the demand of the projected aquaculture production. Although the production of these resources from capture fisheries has remained stagnant over the past decade and any significant increase is not anticipated in the foreseeable future, there will be a substantial decrease in the amount of fishmeal used by the animal production sector. Furthermore, it is also expected that the proportion of fishmeal aquafeeds will be substantially reduced by the increasing use of vegetable-based protein and by greater efficiencies in feeding (Hasan *et al.* 2007). However, great efforts are needed, particularly in appropriate research and technological advances, to make this a reality, for example, to find a full replacement for fish oils. Current aquaculture literature shows that there is increasing interest from private feed companies and research institutions. Under these scenarios, it is unlikely that the supply of fishmeal and fish oil will be a major limiting factor in aquaculture feeding.

One of the greatest constraints could be the impact of climate change on aquaculture. At this stage, climate change presents non-quantifiable threats of changing temperatures, weather, water quality and supply. A recent report examines general predictive models and suggests important differences among regions regarding the magnitude and types of impact on aquaculture (Handisyde *et al.* 2007). The report opens the door to the relevant research needed on this topic and emphasizes the ability to adapt as a major advantage to be developed by countries and regions. There is a need for the aquaculture sector to join other economic sectors in preparing to address the potential impacts of the planet's warming. One of the practical responses to climate change for aquaculture could be to strengthen the adaptive capacity and resilience of the sector, particularly that of small farmers and aquatic resource users. Increased resilience is a desirable feature of any sector; it can mitigate the future impact of unforeseen events (e.g. economic change, disease epidemics and tsunamis), including those related to climate. There is some knowledge and experience from aquaculture itself and from the broader area of agriculture and natural resource management that can be used to increase our understanding. Aquaculture and particularly mariculture can in fact provide adaptation opportunities to produce good-quality protein when freshwater is scarce. In contrast, freshwater aquaculture can produce protein with a higher water saving than other animal production sectors (Verdegem *et al.* 2006).

Science can be useful in understanding and reducing risks, uncertainties and vulnerabilities, but unwavering government will and support are essential elements in enhancing aquaculture development. Although the level of commitment will inevitably vary within and among regions, according to the importance of aquaculture to the national economy, it is expected that in countries where aquaculture contributes, or has the potential to contribute, substantially to food security, nutritional well-being, poverty reduction and economic growth, the commitment will hold and the level of support is expected to increase.

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