Review on aquaculture's contribution to socio-economic development: enabling policies, legal framework and partnership for improved benefits

Expert Panel Review 2.2

Junning Cai[1] (*), Curtis Jolly[2], Nathanael Hishamunda[3], Neil Ridler[4], Carel Ligeon[5] and PingSun Leung[6]

[1] Fisheries and Aquaculture Department, Food and Agriculture Organization of The United Nations, Rome, Italy. E-mail: Junning.Cai@fao.org
[2] Department of Agricultural Economics and Rural Sociology, Auburn University, Alabama, The United States of America. E-mail: Jollycm@Auburn.edu
[3] Fisheries and Aquaculture Department, Food and Agriculture Organization of The United Nations, Rome, Italy. E-mail: Nathanael.Hishamunda@fao.org
[4] Department of Economics, University of New Brunswick, New Brunswick, Canada. E-mail: ridler@unb.ca
[5] Department of Economics, Auburn University at Montgomery, Alabama, the United States of America. E-mail: cligeon@aum.edu
[6] College of Tropical Agriculture and Natural Resources, University of Hawaii at Manoa, Hawaii, the United States of America. E-mail: psleung@hawaii.edu

Cai, J., Jolly, C., Hishamunda, N., Ridler, N., Ligeon, C. & Leung, P. 2012. Review on aquaculture's contribution to socio-economic development: enabling policies, legal framework and partnership for improved benefits. *In* R.P. Subasinghe, J.R. Arthur, D.M. Bartley, S.S. De Silva, M. Halwart, N. Hishamunda, C.V. Mohan & P. Sorgeloos, eds. *Farming the Waters for People and Food*. Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand. 22–25 September 2010. pp. 265–302. FAO, Rome and NACA, Bangkok.

Abstract

The Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000 recognized that aquaculture contributes greatly to people's livelihoods, food security, poverty alleviation, income generation, employment and trade; and that the potential of aquaculture's contribution has not yet been fully realized across all continents. It also recognized that the potential of aquaculture's contribution to human development and social empowerment cannot be fully realized without consistent, responsible policies and goals, effective institutional arrangements and regulatory frameworks, and improved co-operation among stakeholders at the national, regional and inter-regional levels. It suggested that the aquaculture

* Corresponding author: Junning.cai@fao.org

sector should continue to be developed towards its full potential of contributing towards sustainable livelihoods, human development and social well-being.

Through innovations in technology and organization, intensification in operations, and diversification in products, species and culture systems, aquaculture continues growing in the new millennium towards a matured and global industry, accounting for half of the world seafood supply and with a large portion of its products traded across borders. While the sector is still mainly motivated by and promoted for its economic benefits, increasing attention has been paid to aquaculture's environmental and social responsibilities. Learning from past experience of runaway yet unsustainable aquaculture growth, regulations and public policies have been used to establish clear guidelines for resource utilization and promote sustainable practices in aquaculture operations. Public concerns over aquaculture's environmental and social impacts have become more influential through certification schemes initiated by advocacy groups or private entities. Fish farmers have become increasingly aware of the importance of long-term sustainability and more willing to adopt codes of conduct, best management practices (BMPs), farmers groups and other self-discipline mechanisms. In short, the main themes of aquaculture development in the first decade of the new millennium are sustainable economic growth, environmental stewardship and a pro-poor orientation.

Despite the progress made, institutional arrangements for sustainable aquaculture development have only made baby steps and have many aspects to improve. Even though impressive aquaculture development has made the sector increasingly recognized as more than just a branch of fisheries, most countries still lack laws and regulations specifically designed for aquaculture; and thus the sector has to deal with diverse regulations designed by different agencies, probably without consideration of the situation of aquaculture. Even with laws and regulations specifically targeting aquaculture, lack of institutional and human capacity for implementation may render them ineffective. While certification schemes have helped facilitate environmentally and socially responsible behaviours, their proliferation has caused confusion, increased costs of compliance and fostered cynicism that these schemes are no more than marketing trickeries for higher profit margins. Despite increasing awareness, knowledge and technical constraints tend to hinder aquaculturists' attempts to fulfill their environmental and social responsibilities.

In light of this, this paper reviews the socio-economic impacts of aquaculture based on recent experience and discusses how institutional arrangements can facilitate positive development and mitigate negative impacts.

KEY WORDS: *Aquaculture, Legislation, Policy, Socio-economic development, Sustainable aquaculture.*

Introduction

The *Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000* (NACA/FAO, 2000) recognized that aquaculture has made a great contribution to people's livelihoods, food security, poverty alleviation, income generation, employment and trade; and that aquaculture's contribution to human development and social empowerment cannot be fully realized without consistent, responsible policies and goals, effective institutional arrangements and regulatory frameworks, and improved co-operation among stakeholders at the national, regional and inter-regional levels. The Bangkok Declaration suggested that aquaculture policies and regulations should promote economically viable, environmentally responsible and socially acceptable farming and management practices so as to help the sector develop towards its full potential of contributing towards sustainable livelihoods, human development and social well-being.

Through innovations in technology and organization, intensification in operations and diversification in products, species and culture systems, aquaculture continues growing in the new millennium towards a robust and global industry. The total world aquaculture production reached 68 million tonnes in 2008, which is 64 percent higher than the 2000 level.[1] The share of aquaculture production (measured by weight) in the total fisheries production (including both capture and culture products) has increased from 31 percent in 2000 to 43 per cent in 2008.[2] Approximately 32 million tonnes of seafood (worth USD 94 billion) were traded internationally in 2007, which was 20 percent higher than the level in 2000 (nearly 70 percent higher in terms of value).[3] In 2006, there were nearly 8.7 million people engaged in fish farming globally, which was 13 percent higher than the number of aquafarmers in 2000 (FAO, 2009).

While negative environmental impacts were a major liability to its public image, aquaculture development in the new millennium has become more resource conserving and environmentally friendly, thanks to more stringent public scrutiny and innovations in farming technologies and practices. For example, restrictive public regulations have been established in most countries to mitigate aquaculture's negative impacts on natural habitats (e.g. mangroves);

1 Aquaculture production of crustaceans nearly tripled during this period; and the growth for other major species was 86 percent for marine fishes, 70 percent for aquatic plants, 63 percent for freshwater fishes, 47 percent for diadromous fishes and 34 percent for molluscs.

2 The shares of aquaculture in total fisheries have increased for all the species: aquatic animals (from 20 percent to 58 percent), aquatic plants (from 88 percent to 94 percent), crustaceans (from 22 percent to 46 percent), diadromous fishes (from 56 percent to 68 percent), freshwater fishes (from 72 percent to 76 percent), marine fishes (from 1.3 percent to 2.6 percent) and mollucscs (from 56 percent to 64 percent).

3 Approximately 70 percent of seafood traded across borders in 2007 was marine fishes, 10 percent was crustaceans, 9 percent was mollucscs, 7 percent was diadromous fishes, and 3 percent was freshwater fishes. The trade volume growth rates during the period were 270 percent for freshwater fishes, 56 percent for diadromous fishes, 52 percent for crustaceans, 24 percent for molluscs and 10 percent for marine fishes.

certification schemes (e.g. ecolabelling), which enable consumers to express their environmental concerns through market forces, have become increasingly popular; and environmentally friendly practices have been widely promoted within the private aquaculture sector through codes of conduct and better management practices (BMPs) (FAO, 2006; World Bank, 2006).

Increasing effort has also been spent to make aquaculture development more socially acceptable. The role of aquaculture in rural development has been increasingly recognized, and pro-poor has been widely accepted as a main objective of aquaculture development (World Bank, 2006; FAO, 2006, 2009). Almost all the aquaculture growth between 2000 and 2008 was attributable to aquaculture development in developing countries. While aquaculture production in developed countries increased by 7 percent during the period, the growth for developing countries was 70 percent. While half of aquaculture production came from low-income food-deficit countries (LIFDCs) in 2000, their contribution increased to 81 percent in 2008.

Seafood continues to be an important source of protein in the new millennium, contributing 16 percent of animal protein intake (10 percent of total protein) per capita per day in 2007. On average, each person in the world obtained 4.7 g of protein per day from seafood in 2007, which was 7 percent higher than the level in 2000 and 21 percent higher than that in 1990. For LIFDCs, seafood contributed 20 percent (or 25 percent for least-developed countries) of animal protein intake per capita per day in 2007; and each person in these countries on average obtained 3.9 g (or 2.7 g for least-developed countries) of seafood protein per day in 2007, which was 8 percent (or 17 percent for least-developed countries) higher than the level in 2000 and 56 percent (or 28 percent for least-developed countries) higher than that in 1990.[4]

In sum, aquaculture development in the new millennium has made progress towards the goal of being economically viable, environmentally responsible and socially acceptable. Improvement in institutional arrangements is a major contributing factor to this achievement: freer international market access has allowed countries to exploit their comparative advantages and gain from trade; more active public policies and stricter regulations have streamlined the allocation and management of common resources and promoted sustainable practices in aquaculture operations; various certification schemes have made the aquaculture production process increasingly accountable for its environmental and social impacts; and codes of conduct, farmers groups and other self-regulating mechanisms have fostered awareness of aquaculture's environmental and social responsibilities and corresponding modifications of behaviour. Despite the progress made, aquaculture development is expected to continue facing resource, environmental, economic, knowledge and institutional

[4] These figures are calculated based on the FAO Food Balance Sheet.

constraints; and more efficient and effective institutional arrangements are needed to help the sector overcome them.

This paper reviews aquaculture's socio-economic impacts and explores the role of institutional arrangements in promoting sustainable aquaculture. In the following sections, aquaculture's socio-economic impacts are reviewed based on recent experience, and facilitating factors for positive impacts and mitigating measures for negative ones are discussed; institutional arrangements regarding aquaculture development are reviewed and their positive and negative roles in facilitating aquaculture's socio-economic impacts are discussed. The paper concludes with some remarks on the way forward.

Socio-economic impacts of aquaculture

Aquaculture has profound socio-economic impacts. While aquaculture represents a potentially more efficient (than capture fisheries) way of utilizing natural resources to produce aquatic products for food, pharmaceutical, recreational and other purposes, imprudent aquaculture operations could cause environmental degradation, the socio-economic costs of which tend to outweigh the sector's short-term benefits. While aquaculture generates incomes and stimulates local economic growth, aquaculture development may have negative impacts on other industries (e.g. agriculture, fisheries, tourism) because of its environmental externalities and due to resource competition. While rapid aquaculture expansion lowers the price of aquaculture products to the benefit of foreign consumers, domestic seafood producers may nevertheless become worse off. While aquaculture brings new opportunities (e.g highly paid jobs, training, business opportunities) to the community, some stakeholders may become marginalized and worse off.

These are only a few examples of tradeoffs among aquaculture's complex socio-economic impacts that will be reviewed based on countries' recent experience in aquaculture development (FAO, 2006; World Bank, 2006). While there are potentially many ways to categorize aquaculture's socio-economic impacts, this review groups them into environmental impacts, economic impacts and social impacts.

Environmental impacts

Aquaculture operations utilize land, water, wild species, fuel and other natural resources and interact with the surrounding biophysical environment. Sustainable aquaculture development requires the sector to be resource conserving and environmentally non-degrading (FAO, 1989). While aquaculture's negative environmental impacts are often cited as evidence against its development (Allsopp, Johnston and Santillo, 2008), the sector has become more resource conserving and environmentally friendly in the new millennium, thanks to more active public resource management and stricter regulations, innovations in fish

farming technologies and practices, and improved awareness of aquaculture's environmental responsibilities in both the public and private sectors (FAO, 2006).

Habitat conservation

Unsustainable aquaculture practices tend to cause degradation of wetlands, lagoons, mangrove forests, seagrass habitats and terrestrial habitats. While one of aquaculture's most publicized negative environmental impacts was destruction of mangroves (GESAMP, 1991),[5] such impacts have been mitigated in most regions, thanks to stricter regulations (use of mangroves for aquaculture is completely banned in some countries), better coastal planning and management measures (e.g. zoning, enivronmental impact assessment (EIA)) and more environmentally friendly farming technology and practices (FAO, 2006).

In general, awareness of the importance of habitat conservation has been growing, but more effort (e.g. improvements in siting approaches, farm construction and feed management) is needed to protect bottom ecosystems (e.g. coral reef and sea grass) from aquaculture's organic wastes, and freshwater marshes and wetlands from improper aquaculture practices (FAO, 2006).

Land and water

Land and water are two major natural resources essential to aquaculture. Aquaculture can provide environmental services by rehabilitating sodic lands, providing nutrient-rich mud to nearby agricultural land, and reducing nutrient load and heavy metal content in surrounding water through the farming extractive species such as molluscs and seaweeds (FAO, 2006; World Bank, 2006).

However, aquaculture wastes (effluent and sediments) from intensive use of artificial feeds and chemicals (i.e. medicines, disinfectants and antiseptics), if not properly handled, could cause land salinization, eutrophication, algal blooms, chemical pollution and other environmental degradations (STREAM, 2003).[6] Such negative environmental impacts have not only caused conflicts between aquaculture and other sectors,[7] but also contributed to its own disruption, because poor farming environment is a recipe for low yield and

[5] For example, unbridled expansion during the early stage of aquaculture development in Thailand destroyed 25 percent of the country's mangroves forest (GESAMP, 1991). Mangrove conversion for aquaculture in Ecuador and many Southeast Asian countries has caused soil and groundwater salinization and disrupted the livelihoods of local communities (GESAMP, 1991; Sathirathai and Barbier, 2001; Barbier and Cox, 2004).

[6] For example, concentrated shrimp farming activities have led to eutrophication and frequent phytoplankton blooms in Mexican coastal marine waters (Cruz-Torres, 2000). Excessive use of CuSO4 for curing shrimp diseases has caused extremely severe pollution in the water of the Pearl River Delta in China (IISD, 2004).

[7] For example, conflicts among shrimp farmers and confrontations between shrimp growers and other local farmers and residents occurred in Thailand because of the discharge of effluent water into public waterways and coastal areas, the intrusion of saline water into rice fields and the salinization of canals (Jenkins *et al*. 1999; Be, Dung and Brennan, 1999). Similar conflicts between corporate shrimp farmers and fisherfolk also occurred in India (Bhat and Bhatta, 2004).

disease outbreaks. Restricting areas for aquaculture activities through zoning, requiring EIA as a precondition for granting aquaculture licenses or permits, and promoting BMPs in aquaculture operations have been used to reduce aquaculture's negative impacts on surrounding environment (FAO, 2006; World Bank, 2006).

Aquaculture development competes with other activities (e.g. fisheries, agriculture, livestock farming, woodcutting, fuelwood gathering, recreation, settlement and conservation) for natural resources (Barraclough and Finger-Stich, 1996; FAO, 1997; Flah Vandergeest and Miller, 1999).[8] As a new and less-established industry, aquaculture is sometimes not given high priority in allocation of common resources and is subject to high environment protection standards. Use of land and water for aquaculture has been restricted through land use planning and zoning (e.g. in Chile, Mexico and China); and environmentally degrading practices (e.g. using freshwater for salinity control and extracting underground water) strictly regulated (FAO, 2006). Under this situation, resource-conserving aquaculture practices have been adopted; examples include using land unsuitable for other purposes, rotating use of land for agriculture and fish farming, integrated agriculture and aquaculture operations (e.g. rice-fish farming) and using recirculation or closed-water systems, among others (FAO, 2006).

Wild species

Aquaculture can help preserve wild fish stocks by supplying more affordable aquatic products and hence reducing the pressure on fisheries (Tisdell, 2004). Aquaculture can also increase wild fish stocks through restocking programmes (Petr, 1998). However, environmental degradation caused by aquaculture may negatively affect wild species. In addition, collection of wild seed and broodstock, introduction of exotic species and aquaculture escapees may also have negative impacts on wild stocks (FAO, 2006; World Bank, 2006).

Most aquaculture species still rely on wild stocks for seed or broodstock. As collection of wild seed and broodstock tends to damage not only the targeted wild stocks but also those of bycatch species,[9] increasing public concerns over biodiversity have put it under stricter scrutiny and regulation; some countries (e.g. Egypt) have established official fry collection centers or have used licensing to regulate such activities (FAO, 2006). However, because in some countries wild seed and broodstock collection is a lucrative business providing the livelihoods for many low-income people, public attempts to restrict it tend to be difficult because of social pressure, or they may not be effective because of black markets (FAO, 2006).

[8] A survey on shrimp farming in Thailand found that 49 percent of the land used by shrimp farms was previously rice fields and 27.5 percent used to be orchards (Jenkins *et al.*, 1999).

[9] Confrontations have occurred in Mexico between fishermen and shrimp farmers over collection of shrimp larvae (Cruz-Torres, 2000).

Advances in artificial breeding technology have helped reduce aquaculture's dependence upon wild seed resources for an increasing number of species (milkfish, tiger prawn, mangrove crabs, etc.). One notable achievement is success in hatchery-breeding specific pathogen free (SPF) whiteleg shrimp (*Litopenaeus vannamei*), which has led to a big leap forward of the shrimp farming industry in the new millennium. The scarcity of seed resources is expected to continue driving progress in artificial breeding through the market mechanism, while more public supports and better partnership between scientific researchers and the private sector are needed to speed up the process (FAO, 2006).

Other controversial issues include the introduction of exotic species and aquaculture escapees, which may negatively affect wild stocks through habitat competition, disease spread and gene contamination (APEC/FAO/NACA/SEMARNAP, 2001). Genetic resource management (e.g selective breeding, hybridization, chromosome-set manipulation, genetic engineering) is a common practice in aquaculture, which has significantly improved the productivity of farmed species (FAO, 2006). However, such farmed species, once let into the wild environment, may intrude genetic integrity and cause ecological disruption (Naylor *et al*., 2005). While the damaging impacts of farmed species in the wild are not entirely clear, public concerns over biodiversity and biosecurity have led to stricter regulations (e.g. requirement of import risk assessment) prior to introducing new species or strains for aquaculture (FAO, 2006, Arthur *et al.*, 2009). Various measures (e.g. removal of escapees as a precondition for farm licenses, selecting sites with least impacts on wild stocks, promoting aquaculture practices that prevent escapes) have been applied to reduce the impacts of farmed species on wild stocks; further studies on the impacts of cultured species on biodiversity are needed (World Bank, 2006).

Energy

Although many aquaculture operations (e.g. pumping, water circulation, aeration, lighting, transport, refrigerating) require energy, energy consumption in aquaculture has received relatively little attention. However, this situation may change soon, as energy prices have increased substantially. Intensive aquaculture has been promoted to conserve natural resources, but as intensive operations (e.g. water recirculation systems) tend to be highly energy consuming, the tradeoffs between reducing aquaculture's direct environmental impacts and increasing its indirect impacts (through using more energy) need to be evaluated (e.g. through full life-cycle analysis) to determine whether intensive operations are more environmentally friendly than extensive aquaculture (FAO, 2006).

Economic impacts

While initially being promoted as a supplemental activity to agriculture for enhancing food security and providing extra cash to rural farmers, aquaculture has now developed into a highly commercial business in some places, accounting for nearly half of world aquatic product supply and with a large portion of its products traded across borders (FAO, 2009).

Contribution to economic growth

Aquaculture contributes directly to economic growth by providing wages and jobs to workers, profits to business owners and tax revenues to governments, as well as foreign exchange. Aquaculture development also induces income and employment generation in downstream industries (e.g. fish traders, seafood processing plants, supermarkets, restaurants, pharmaceutical companies) and upstream industries (e.g. seed collectors, hatcheries, feed producers). Increases in household, business and government incomes from aquaculture development would further stimulate the local economy through consumption, investments and government programmes. Aquaculture development would also tend to facilitate development of infrastructure and financial institutions, which would become public goods beneficial to the entire community (Hishamunda, Cai and Leung, 2009). Aquaculture's contribution to economic growth is one of the reasons why experts think aquaculture should be encouraged (Hishamunda, Poulin and Ridler, 2009).

While aquaculture has greatly increased its economic contribution in the new millennium (FAO, 2009), it is still a less-established sector than fisheries or agriculture. However, aquaculture's various economic linkages can make it a key sector and engine of growth for communities with comparative advantages in aquaculture. Examples include salmon farming in Chile and shrimp farming in Thailand, Ecuador and Madagascar (FAO, 2006). Unfortunately, aquaculture's linkage impacts are usually difficult to quantify because of lack of data and systematic knowledge about the sector's economic linkages to the economy, which tends to result in underestimation of aquaculture's contribution to economic growth. Indeed, even the measure of aquaculture's direct contribution to value added needs improvement. While aquaculture's production value is commonly used to gauge its contribution to gross domestic production (GDP), the measure may not be accurate because production value tends to be influenced by value added belonging to foreign countries (e.g. the value of imported feed), as well as non-market forces such as subsidies. As aquaculture's economic contribution is important information needed by policy-makers to determine the allocation of public resources, further research in this area is warranted.

Impacts on other industries

Aquaculture tends to compete with other sectors for natural resources, human resources, financial resources, government funding, markets, etc.; and its environmental externalities may negatively affect other sectors. Thus, rapid aquaculture development has led to conflicts between aquaculture and other sectors (FAO, 2006).[10] While aquaculture's negative externalities should be reduced to a minimum by integrating aquaculture into the entire economic development plan, it should be realized that competition among sectors is

[10] For example, conflicts occurred between aquaculture and tourism/recreational activities in the Mediterranean and Adriatic seas, and with small-scale fisheries in Latin America (FAO, 2006).

inevitable and may actually be a positive factor because resources should be allocated to more efficient sectors, and the development of these sectors would stimulate economic growth that benefits all the sectors.

A case in point is the relationship between aquaculture and fisheries. While aquaculture is often viewed as a competitor of fisheries, the great potential in seafood demand actually allows aquaculture to be a complement to rather than a substitute for fisheries. Aquaculture development can benefit the fisheries sector by increasing demands for fisheries products (e.g. fishmeal and fish oil as feed ingredients), enlarging the market base for seafood and perhaps creating a niche for captured products, reducing costs of seafood processing and marketing, and motivating the fisheries sector to be more efficient (Anderson, 2007).

However, in the short run, policy-makers have to determine how to distribute limited public resources efficiently. Such decision-making requires information about the country's or region's comparative advantages in different sectors. Unfortunately, such information is rarely available because of lack of research in this area.[11] This makes it more difficult for aquaculture, as a latecomer, to compete with established sectors for public resources.

Competition within aquaculture

Aquaculture has become an increasingly commercial business in the new millennium. While freer market access gives countries opportunities to gain from their comparative advantages in aquaculture, it also increases the level of competition in the sector, which has resulted in significant price decline in many cultured species such as carps, tilapia, shrimp, salmon and Japanese eel (FAO, 2006).

While competition is a positive factor that benefits consumers with lowered prices and motivates technological advances, species diversification, new markets and quality improvement (FAO, 2006), harsh competition may disrupt the industry and cause serious damages in the short run, especially when fish farmers, under the pressure of low profit margins, choose to adopt unsustainable farming practices (Bai, 2008).

Competition has also led to trade disputes.[12] Seafood exporting countries (mostly developing countries) complained that importing countries (mostly developed

[11] While there are a few studies using the domestic resource costs (DRC) or revealed comparative advantages (RCA) methods to evaluate comparative advantages in aquaculture production or trade (Cai and Leung, 2007; Cai, Leung and Hishamunda, 2009), there is a lack of studies on assessing a country's or region's comparative advantages in aquaculture relative to other competing sectors. A major constraint in this line of research is the lack of appropriate data.

[12] For example, the antidumping measures used by the United States of America in the early 2000s to restrict shrimp and catfish imports were allegedly intended to protect domestic seafood producers (World Bank, 2006).

countries) used antidumping tariffs, stringent market standards or other barriers to protect inefficient domestic industries, while importing countries accused seafood exporters of gaining unfair competitive advantage through ignoring environmental and social costs and asked for leveling of the playing field. Such disputes are unfortunate; low exporting prices are actually not in the interest of exporting countries because they tend to lower their incomes from aquaculture production.[13] Although it is not sensible or possible for fish farmers to form a cartel to limit production for higher revenues, fish farmers as well as policy-makers should understand that demand for seafood is constrained by people's incomes and preferences, and that increasing the supply to already saturated markets would only lower prices without increasing revenues. While boom-bust cycles may be a common adjustment process under the competitive market mechanism, severe price fluctuations tend to cause hardships for fish farmers, especially small-holder fish farmers who lack bargaining power and tend to be price-takers in both input-purchasing and output-selling markets.

How to avoid flooding the market is a challenge faced by fish farmers that compete for common markets (Lovatelli *et al*., 2008). When there is excess supply in international markets, governments tend to stabilize seafood prices by promoting domestic consumption and helping fish farmers explore other markets. While such remedies are helpful, it is equally important to provide timely information about market demand and competition conditions at all levels (i.e. global, regional, domestic, and local) to prevent market glut. Modern information technology (e.g. Internet) makes such information a valuable yet affordable public good that can benefit many stakeholders and lead to more orderly market conditions.[14]

Social impacts

Being socially acceptable is another objective of aquaculture development in the new millennium. While being economically viable and environmentally responsible are two basic requirements for aquaculture to be socially acceptable, the sector is expected to contribute to various social objectives, including poverty alleviation, food security, human development, and empowerment of women, among others.

Poverty alleviation

Uneven distribution of the benefits and costs of rapid aquaculture development among different groups of stakeholders would tend to cause social conflicts and disrupt the original social order. Thus, pro-poor development is a major challenge of aquaculture activities in the new millennium (World Bank, 2006).

[13] For example, according to FAO FishStat data, the volume of Ecuador's shrimp export was nearly 40 percent higher in 2006 than in 1996, while the value of the export was nevertheless 5 percent lower.

[14] For example, there are numerous Websites in China providing all kinds of information related to aquaculture, such as technology, input prices, daily seafood retailed prices, etc. (Cai and Leung, 2006).

There is ample evidence indicating that aquaculture can make a significant contribution to poverty alleviation (World Bank, 2006; De Silva and Davy, 2010). As a novel way of utilizing natural resources, aquaculture provides rural farmers alternative livelihood means (Gurung *et al*., 2010). As a new and rapidly expanding sector with great market potential and frequent technical breakthroughs, aquaculture can provide higher incomes to rural farmers than traditional agriculture and fisheries activities (World Bank, 2006; Mente *et al*., 2007). Integrated agriculture-aquaculture operations such as rice-fish farming allow rural farmers to increase productivity and diversify their income sources (Miao, 2010).

While economic growth lays the foundation for poverty alleviation, poor people need extra attention because there are various constraints hindering them from enjoying the benefits of economic growth. In aquaculture, poor rural farmers usually lack capital and access to credits, technical skills and management expertise, political influence and bargaining power. These constraints put them in disadvantageous situations in resource allocation and competition and hinder them from enjoying the benefits of aquaculture development (Ahmed and Lorica, 2002). Sustained public supports (e.g. tax exemption and subsidies, infrastructure construction, providing quality seed, capacity building through information exchange, training and extension, promoting technology innovations and transfer) have been a key to neutralizing such constraints and helping the poor enjoy the benefits of aquaculture development (World Bank, 2006).

For the purpose of poverty alleviation, public policies and supports often lean towards promoting small-scale aquaculture. In Asia, where small-scale farmers are the dominant force in aquaculture, there are pro-poor regulations to prevent monopolization by forbidding transfer of aquaculture licenses or permits, limiting farm size and requiring large operations to be nucleus farms that assist small-scale farmers (Hishamunda *et al*., 2009).[15] Small-scale aquaculture operations tend to be more flexible and resistant to negative shocks because the costs of terminating them in bad times and restarting in good times are relatively small as compared to those of large-scale operations (Kongkeo and Davy, 2010). However, small-scale operations have disadvantages such as lack of resources and technical know-how, being difficult to coordinate, lack of economy of scale, weak bargaining power, etc.[16] While public supports and farmers' groups as well as other institutional arrangements can help small-scale farmers mitigate such shortfalls (World Bank, 2006), it remains questionable whether it is wise

[15] Under the nucleus-estate model, commercial farms that wish to gain economy of scale from large operations have to agree to distributing grow-out ponds to landless farmers for their eventual ownership and providing material, technological and marketing supports to help these farmers become economically viable (Hishamunda *et al*., 2009).

[16] The compliance costs for satisfying stringent food safety standards established by developed countries are often too high for unorganized small-scale farmers, who tend to be forced out of business (FAO, 2006).

to intentionally restrain the development of large-scale operations in order to protect small-scale farmers, even from the pro-poor perspective, because large commercial enterprises can also be pro-poor by supplying leadership, knowledge and innovation (World Bank, 2006).[17]

Another controversial issue is the choice between low-value and high-value farming species. Farming low-value species (e.g. carp) is less demanding in technology and management and can bring food to the table. However, the profitability of farming low-value species is usually low because of limited market potential. Farming high-value species (e.g. shrimp), on the other hand, tends to be more profitable yet more difficult and risky, especially for farmers who lack financial resources, technical skills and management expertise. Thus, there are concerns that farming high-value species, notwithstanding its high profitability, may marginalize the poor. However, this may not necessarily be the case when poor farmers who are unable to take on aquaculture by themselves can still benefit from the economic impacts of aquaculture development.[18]

While much effort from governments and development agencies has been spent to promote subsistence, low-trophic-level aquaculture for the purpose of poverty alleviation and food security, business-oriented aquaculture has received relatively less public support.[19] However, evidence indicates that farming high-value species for export may be a better alternative to realize the goal of poverty alleviation than farming low-value species for local markets or personal consumption because of the former's large profit potential (World Bank, 2006).[20]

Food security

Aquaculture can contribute to food security from several aspects: seafood from aquaculture provides high-quality protein and other nutrients, commercial aquaculture provides incomes and foreign exchanges that can be used to purchase food from local or international markets, and aquaculture production expansion makes seafood cheaper and more accessible to low-income people (FAO, 2006; Kawarazuka and Béné, 2010). Aquaculture's contribution to food

[17] Unlike Asia where aquaculture operations are mostly small scale, Latin America's aquaculture is dominated by large commercial operations. Comparing the impacts on poverty alleviation of these two different industrial organizations may provide insights about this issue.

[18] For example, while brackishwater aquaculture in the Philippines was relatively concentrated in the hands of rich farmers, poor households also received large benefits because development of the industry generated a large demand for unskilled labour (Irz *et al.*, 2007).

[19] According to a survey of the opinions of aquaculture experts, major constraints to aquaculture development in Africa include the predominance of government or donor-driven investments promoting subsistence aquaculture and the lack of policies supporting profit-driven commercial aquaculture (Hishamunda, Poulin and Ridler, 2009). In contrast, in West Bengal, India, a shift of economic policy to export-led growth has resulted in rapid shrimp farming development in the region (World Bank, 2006).

[20] For example, the annual return from farming 2 000 grouper in the Philippines is equal to growing 30 000 milkfish, and the former requires only half as much investment as the latter (Hishamunda *et al.*, 2009).

security is one of the reasons why experts think that the sector should be encouraged (Hishamunda, Poulin and Ridler, 2009).[21]

However, aquaculture may have negative impacts on food security. For example, aquaculture's impacts on the local biophysical environment may negatively affect the food security of stakeholders (i.e. agricultural farmers and fishers) whose activities compete with aquaculture for natural resources (World Bank, 2006). While access to the international market allows countries to exploit their comparative advantages and gain from trade, there are concerns that export-oriented policies may divert resources away from other important domestic food sources such as small fisheries (FAO, 2006). Moreover, overly specializing in a couple of export species would put the country in danger of economic disasters from price fluctuations, disease outbreaks, natural disasters, etc.[22]

Another concern is that profit-driven aquaculture production may not utilize natural resources in the best way for food security. One well-publicized issue is that the farming high-valued species (mostly carnivorous marine species) may be an economically profitable but biologically wasteful process that uses more biomass to produce less (Naylor *et al.,* 2000). Using fish suitable for direct human consumption to produce feed materials for aquaculture may drive up the prices of low-value fish and hence negatively affect the food security of low-income households (Tacon and Metian, 2009). Although small fish are generally more nutritious and affordable (Kawarazuka and Béné, 2011), aquaculture nevertheless prefers to culture bigger species that are more economically profitable (Ahmed and Lorica, 2002). While farming high-value or bigger species may not be an efficient way of supplying nutrient from a biological perspective, it is not necessarily bad for food security because incomes and foreign exchange from selling cultured seafood can be used to purchase food from domestic or international markets (Hasan and Halwart, 2009). Indeed, a large portion of seafood products are traded across borders, with developing countries being main exporters and developed countries being main importers; undernourished countries produce high-value seafood for export and import low-value fish for their own consumption (Smith *et al.,* 2010). However, in the long run, relying on low-trophic-level fish as inputs to produce high-trophic-level species may not be sustainable (Tacon *et al.,* 2010).

The impacts of increasing commercialization and globalization of aquaculture production on food security are complex and not well understood. While the

[21] Aquaculture accounted for 47 percent of fish available for per capita world human consumption in 2006, increasing from 30 percent in 1996 and 14 percent in 1986 (FAO, 2009). Aquaculture provides 22 percent of protein intake in sub-Saharan Africa, where hunger has been a major problem (FAO, 2006).

[22] For example, Ecuador's shrimp farming industry lost about half a million jobs in 2000 because of white spot syndrome virus (WSSV); and consequently the Government of Ecuador had to declare a state of emergency to help workers and growers who suffered from income and employment losses (FAO, 2006).

declining prices of high-valued seafood (e.g. shrimp and salmon) in the new millennium have made them more accessible to common people (FAO, 2006), the prices of low-valued captured fish are nevertheless driven up by increasing demand for aquaculture feed (Smith *et al.,* 2010), which would benefit rural farmers who are net food producers but harm those who are net food consumers (Godfray *et al.* 2010). However, evidence indicates that the prices of low-value cultured fish (e.g. carp) have declined because of aquaculture development (FAO, 2006). The need for research to identify the impact of increasing commercialization and globalization of aquaculture on food security is a key issue.

Human development

There were around 8.7 million people directly engaged in fish farming in 2006 globally (FAO, 2009), and the number is expected to be much higher when people engaged in aquaculture-related businesses (e.g. seafood processing) is taken into account (FAO, 2006).[23] There is evidence indicating that aquaculture workers can earn higher wages (e.g. from catfish farming in Viet Nam) than workers involved in other agricultural activities (World Bank, 2006), while there are also reports indicating that aquaculture workers (e.g. in the salmon industry of Chile) were subject to hardships such as low wages, long working hours, and no union rights (Allsopp, Johnston and Santillo*,* 2008).

In addition to providing incomes and jobs, aquaculture contributes to human development through improving human health. As a food producer, aquaculture contributes to human health by providing high-quality protein and other nutrients (e.g. minerals, vitamins, fatty acids). Active human interventions in the production process allow aquaculture to improve the nutritional value and taste of aquatic products (Hasan, 2001). Aquaculture can also alleviate food safety problems (e.g. chemical and metal contamination, infectious diseases, parasites) by raising fish in controlled environments (Howgate *et al.,* 1997). However, there is a general perception that cultured products tend to be less nutritious, healthy and tasty than wild seafood. While this may be an outdated and misinformed opinion, it nevertheless reflects the fact that poor farming environment, low-quality feed ingredients, and imprudent use of chemicals in farming and processing methods can negatively affect the quality of aquaculture products (FAO/NACA/WHO, 1999; FAO, 2006), which in turn, would tend to negatively affect human health (GESAMP, 1991). Under the pressure of more stringent food safety regulations and more demanding consumer demands, the quality of cultured products has been improved and is expected to continue improving.

In addition to providing healthy food, aquaculture can also have positive impacts on human health by controlling human disease vectors (e.g. mosquitoes and snails). However, abandoned or poorly managed aquaculture ponds may

[23] Employment data in aquaculture are rarely available; the number of jobs provided by aquaculture is sometimes estimated from other data such as production figures (Hishamunda *et al*., 2009).

cause water-borne diseases (Brugere, 2006). Aquaculture operations are also associated with occupational hazards such as animal bites, stings from fish spines, slips, trips, falls from heights, machinery accidents, excessive noise exposure, chemical or biological exposure, confined working spaces, etc. (Erondu and Anyanwu, 2005; Moreau and Neis, 2009).

Aquaculture can not only make people healthier but can also help them to become smarter. As aquaculture becomes increasingly sophisticated and knowledge intensive, fish farmers' knowledge and skills have improved accordingly (World Bank, 2006). While training and extension provided by governments or private companies are a major contributing factor to such human capital accumulation, the opportunity to take part in a vibrant and competitive industry is the most effective training ground for capacity building.

Empowerment of women

Many aquaculture operations (e.g. seed collection, postharvest processing and trading) are suitable for women's participation. However, negative social attitudes as well as other obstacles (e.g. lack of land) tend to hinder women from taking such opportunities (Ahmed and Lorica, 2002). Experiences of countries with women's involvement in aquaculture differ. While there are many women in the aquaculture work force (especially as hired labour in processing plants) in Bangladesh, Thailand and Viet Nam, women's participation in aquaculture is low in Malaysia and Myanmar (Karim *et al.,* 2006; Hishamunda *et al.,* 2009). While women's involvement in aquaculture is insignificant in the Near East and North Africa, they play a dominant role in fish processing and trading in western and some southern African countries (FAO, 2006). While such discrepancies may reflect different cultural, ethnic or religious traditions, further research on factors affecting women's roles in aquaculture is needed to facilitate better understanding of aquaculture's contribution to the empowerment of women. In general, while there is still gender imbalance in aquaculture employment (FAO, 2006), opportunities provided by aquaculture have contributed to empowering women and improving their status and well-being (Brugere and Kusakabe, 2001; Brugere, McAndrew and Bulcock, 2001).

Community cohesion and social order

While rural youth in developing countries often go to urban areas for higher paid jobs and more opportunities, business and employment opportunities brought by aquaculture development can check such a tendency and retain important human resources for rural development (NACA, 1994). Rapid aquaculture development may actually attract immigration of labour to local communities, which would nevertheless put pressure on the original social order and cause social conflicts (Rijsberman, 1999; Lewins 2006).

As discussed above, while incomes, jobs, infrastructure and other economic contributions of aquaculture tend to have positive impacts on rural development,

aquaculture's competition and negative environmental externalities have caused conflicts between fish farmers and other stakeholders and disrupted social order. Experiences in many countries indicate that when profit-driven aquaculture results in a large amount of resources flowing into the production of a highly profitable single crop (e.g. shrimp), some local people are able to grab the opportunity and become better off, while others are marginalized because of various constraints; and worse still, their requirements for livelihood and environment were often neglected (Barraclough and Finger-Stich, 1996). The resulting increase in inequality tends to cause social conflicts.

When export-led commercial aquaculture opens rural communities to the outside world, the traditional values and way of life would tend to be impacted. People may become more open, ambitious and competitive and pay increasing attention to financial success. Traditional customs and the cultural heritages of indigenous people may be suppressed by profit-seeking aquaculture activities. As a highly profitable and regulated business, aquaculture development may foster rent-seeking behaviours.[24] While such impacts have complicated and significant implications for stakeholders' social well-being, research in this area is generally lacking.

Institutional arrangements and sustainable aquaculture development

While an environmentally responsible, economically viable and socially acceptable aquaculture sector is an outcome perhaps desirable for everyone in the long run, it is nevertheless difficult to achieve because of coordination failures caused by unclear or unprotected property rights, externalities, imperfect information, high transaction costs and other constraints. Public interventions are often applied to neutralize or mitigate such constraints, which nevertheless may not be effective and sometimes can be counterproductive. Thus, appropriate institutional arrangements are needed to align various stakeholders' interests, encourage cooperative behaviour and facilitate win-win solutions.

Aquaculture development in the new millennium has witnessed an increasing trend of command and control measures being replaced by economic incentives and more management responsibilities being transferred from public administration to the private sector. Co-management through partnership among various stakeholders (e.g. governments, aquaculturists, researchers, civil societies) has been promoted to create a democratic and transparent decision-making process for more realistic, implementable and effective policies. Public policies and programmes, quality standards and certification schemes, as well as voluntary codes of conduct and self-regulatory practices have been adopted

[24] For example, public tilapia hatcheries in the Philippines are sometimes viewed as a source of corruption (Hishamunda *et al.*, 2009).

or encouraged to move the sector towards the goal of being economically viable, environmentally responsible and socially acceptable.

Despite the progress made, institutional arrangements for aquaculture development have not been well developed in some countries. Problems include lack of specific legal framework, lack of well-defined policy goals, lack of specific strategies to implement policies, ineffective policies because of poor awareness or shortage of human capacity for implementation, etc. (FAO, 2006).

In the remainder of this section the role of institutional arrangements in facilitating sustainable aquaculture development is reviewed and the underlying causes of environmental, economic and social constraints on sustainable aquaculture development are analyzed; existing and potential institutional arrangements for neutralizing or mitigating these constraints are discussed; and the tradeoffs among aquaculture's environmental responsibility, economic viability and social acceptability are highlighted.

Institutional arrangements for environmentally responsible aquaculture

There are several obstacles hindering aquaculture from being environmentally responsible. These include knowledge constraints (fish farmers may not be aware of the negative environmental impacts of their operations or not know how to avoid or mitigate such impacts), externalities (fish farmers do not need to pay for the negative environmental impacts of their operations on others), and coordination failures (fish farmers are not willing to individually internalize their externalities because of the pressure of competition), among others. Various institutional arrangements can be applied to discourage environmentally degrading activities through legal or regulatory forces or to encourage environmentally responsible behaviours through market forces or by facilitating coordination and cooperation.

Laws and regulations

Laws and regulations are the most common measures to address the resource and environmental problems of aquaculture development. With increasing concerns about environmental protection, countries worldwide have become more active in regulating nearly every aspect of aquaculture operations (e.g. site selection, farm size, use of water, feed, chemicals, and wild species, disease control, escapee control); environmentally degrading aquaculture activities are either highly restricted or completely prohibited. However, since aquaculture is still a relatively small and not yet fully established sector, most countries lack a comprehensive regulatory framework specifically for the sector. There are usually no independent aquaculture laws but only aquaculture-related chapters or clauses under more general fisheries laws, and environmental regulations applicable to aquaculture are usually established and implemented by diverse agencies with little consideration or coordination in accounting for

aquaculture's specific situations (FAO, 2007b; Hishamunda *et al.,* 2009).[25] In addition, difficulties in monitoring and enforcement tend to make environmental regulations over aquaculture ineffective.[26]

Notwithstanding being arbitrary and inflexible, laws and regulations are essential institutional arrangements for making aquaculture environmentally responsible because they establish clear guidelines to enforce sustainable behaviours by the sector. However, enforcement of laws and regulations tends to be costly, and their effectiveness requires good governance that is usually lacking in developing countries. In addition, inappropriate or cumbersome laws and regulations tend to inflict undue costs upon and hence constrain aquaculture development. Countries' experiences indicate that effective and efficient aquaculture laws and regulations require the active involvement of the private sector (FAO, 2007b).

Evidence indicates that government regulations tend to be more stringent in countries that have already paid high environmental costs for aquaculture development (e.g. Thailand and the Philippines) than in newcomers, such as Myanmar and Viet Nam (Hishamunda *et al.,* 2009), which indicates that government regulations tend to be reactive for mitigating existing environmental problems rather than proactive for preventing potential problems. This is understandable because government usually puts more emphasis on economic growth (as a benefit) than on environmental protection (as a cost), and the biophysical environment may be too complex for anyone to practically know in advance when nature's carrying capacity would be reached.[27] However, considering the tremendous costs of environmental degradation to society as well as to the industry *per se*, further research on how government policies can strike a proper balance between economic growth and protection of the environment is warranted.

Environmental impact assessment

Environmental impact assessment (EIA) has been increasingly used to avoid or reduce aquaculture's negative impacts on the environment. Many countries in Latin America now require mandatory EIA as a precondition for granting

[25] For example, "the regulatory structure for aquaculture often does not allow or facilitate a production mode or approach that is conducive to a balanced ecosystem. Nutrient cycling and reutilization of wastes by other forms of aquaculture (polyculture) or local fisheries are frequently prohibited or discouraged" (FAO, 2007b, p. 78). See Agüero, Hishamunda and Valderrama (2009) for a detailed review of aquaculture laws and regulations in Latin America, and Hishamunda *et al.* (2009) for the situation in Asia.

[26] For example, prohibitions of using mangroves for aquaculture in the Philippines and Viet Nam had little impact because of lack of resources and human capacities to enforce the regulations (Agüero, Hishamunda and Valderrama, 2009).

[27] For example, in spite of past disease outbreak experiences of salmon farming in Norway and shrimp farming in Latin America and Southeast Asia, Chile's salmon farming industry did not avoid being the victim of a recent disease outbreak that wiped out nearly half of the industry's production (Barrionuevo, 2008; Arengo *et al*., 2010).

aquaculture licenses or permits. However, EIAs are usually not required for existing aquaculture operations and hence do not provide detailed information about mitigating measures for addressing existing environmental problems (FAO, 2007b).

The applicability of EIA to small-scale operations tends to be limited because it usually evaluates the environmental impacts of individual operations independently without considering their potential aggregate impacts (FAO, 2007b). Also, the compliance costs for EIA tend to be burdensome for small-scale operations. Thus, in Asia, EIA is usually required only for large operations (Hishamunda *et al.,* 2009).[28]

Environmental taxes

Based on the "polluter pays" principle, environmental taxes can be used to internalize individuals' negative environmental externalities and hence discourage environmentally degrading behaviours. While the idea is theoretically sound, this method faces practical problems in aquaculture, such as difficulties in determining appropriate tax rates and in monitoring environmentally degrading activities or assessing negative environmental impacts. Thus, environmental tax is rarely applied in aquaculture.[29]

Ecolabelling

Ecolabelling is, in essence, a scheme that uses market force to encourage environmentally responsible behaviours, under which goods produced with environmentally friendly practices are trademarked (usually through third-party certification) and catered to consumers who are concerned about environment protection. Ecolabelling has become increasingly popular in aquaculture and is used widely in developed countries' marketplace (Ababouch, 2007; Siggs, 2007; Ward and Phillips, 2008).

While theoretically ecolabelling tends to encourage environmentally friendly behaviours in aquaculture, practical issues may render the scheme ineffective or even counterproductive. Firstly, certification costs, if higher than the extra profit (price premiums less compliance costs) brought by ecolabelling, would not only be ineffective in inducing environmentally friendly behaviour but would also tend to discourage fish farmers who would adopt environmentally friendly operations even without ecolabelling. Secondly, ecolabelling may deviate from its original mandate of environmental protection and become a marketing strategy (e.g. retailers may use ecolabelling or other market standards to gain market power) (Ababouch, 2007). Thirdly, without proper regulation, the coexistence of an increasing number of ecolabelling and other certification schemes sponsored

[28] For example, in Indonesia, EIAs are "required for farms of at least 50 ha in brackishwater zones, and for larger farms in lakes and in marine waters." (Hishamunda *et al.*, 2009).

[29] There is no report of environmental taxes being used in aquaculture in a series of regional reviews of aquaculture status in 2006 (FAO, 2006).

by governments, advocacy groups or private companies would tend to confuse consumers and reduce the effectiveness of ecolabelling as a whole (Ababouch, 2007). Fourthly, complicated and costly application and compliance procedures would make ecolabelling discriminate against small-scale farmers (Phillips, Ward and Chaffee, 2007).

While ecolabelling may be a better scheme to express consumers' environmental concerns than boycotts or consumer choice guides, the environmental as well as economic impacts of ecolabelling or other certification schemes in aquaculture are yet to be fully understood (Roheim, 2009). Further study in this area is warranted.

Self-regulation

Institutional arrangements discussed above use either legal-regulatory or market-driven incentives to discourage environmentally degrading behaviours or motivate environmentally responsible behaviours. These mechanisms tend to be costly and may not be effective because of poor governance. When applied to a large number of small-scale farmers, such schemes tend to be even more costly and less effective. Thus, self-regulation has been promoted as a complementary approach to protect the environment (FAO, 2006). To be effective, self-regulation needs clear guidelines for environmentally responsible practices and coordination mechanisms to facilitate them. Technical and financial supports may also be needed to make these practices economically viable.

Codes of conduct (or technical guidelines) have been established by governments, international agencies or private companies to increase the awareness of and provide clear guidelines for environmentally responsible aquaculture operations; the most well-known is the FAO *Code of Conduct for Responsible Fisheries* (FAO, 1995). There are a number of aquaculture-related codes of conduct or technical guidelines at the international level (sponsored by international agencies such as FAO, the International Council for the Exploration of the Sea (ICES) and the Network of Aquaculture Centres in Asia-Pacific (NACA)), the national level (sponsored by individual governments) and the industry level (sponsored by producers associations or large private companies).[30] While much effort has been spent in promoting these codes of conduct, fulfillment of these voluntary codes is difficult to monitor or verify, especially for a large number of small-scale farmers (FAO, 2006).

Farmers associations have been playing an important role in promoting environmentally responsible aquaculture practices among small-scale fish farmers (FAO, 2006). Peer pressure and role models sometimes can be more effective in inducing responsible behaviour than legal-regulatory or market

[30] See World Bank (2006, Annex 2) for a list of aquaculture-related codes of conduct and technical guidelines.

forces because their impacts tend to be more direct, timely and straightforward. Coordination under farmers associations can also facilitate training and extension, information, experience and risk sharing, access to financial resources and public supports and increase farmers' bargaining power. Countries' experiences indicate that being organized is one key factor for successful adoption of best management practices (BMPs) among small-scale fish farmers (FAO, 2006).

Best/better management practices (BMPs) are a means to sustain environmentally responsible aquaculture behaviours being voluntarily adopted by small-scale farmers. Countries' experiences indicate that BMPs, when taken by most farmers in a coordinated manner will not only reduce negative environmental impacts but can also increase fish farmers' profitability by raising productivity and reducing the costs of disease prevention and outbreaks (FAO, 2006).[31]

Institutional arrangements for economically viable aquaculture

Aquaculture development in the new millennium has been driven by free market access and facilitated by technological innovations. While population growth, economic growth and increasing consumers' preference for healthy food are expected to sustain strong seafood demand in the future, aquaculture faces constraints such as a lack of suitable sites, shortage of seed and feed, high energy prices and lack of infrastructure, among others (FAO, 2009). While environmental protection requires that fish farmers' behaviours be restricted, facilitating the economic viability of aquaculture requires that constraints be removed to facilitate the proper functioning of the market mechanism.

Trade barriers

Tariffs

Tariffs over seafood imports in developed countries (as the main seafood import markets) are generally low (FAO, 2009), but there are still "tariff peaks" and "tariff escalation" on value-added products from developing countries, which tend to constrain the development of the seafood processing industry in developing countries (Li, 2007). Also, tariffs for seafood imports in developing countries are relatively high, which tends to restrict free trade among developing countries (World Bank, 2006). Nevertheless, under the general trend of globalization and free trade, tariffs are not expected to become a major trade barrier for aquaculture products in the future.

[31] For example, adoption of better management practices for shrimp farming under shrimp health management projects in India has led to "reduction in disease prevalence by 65 percent, two-fold increase in production, 34 percent increase in size and improvement in quality of shrimps due to non-use of banned chemicals"; and in Viet Nam, the results were "1.5 times higher seed production by better managed hatcheries with 30 to 40 percent higher selling price for the fry, higher production and higher probability of making a profit, improved yields that were up to four times higher than non-BMP ponds." (FAO, 2006, p.107).

Antidumping

Antidumping is a trade barrier often used by developed countries against cheap imports. Antidumping measures were used by European countries and the United States of America to restrict salmon imports in the 1990s (Asche, 1997), and by the United States of America to restrict shrimp and catfish imports in the 2000s (World Bank, 2006; GLOBEFISH Highlights, 2009). Although antidumping charges are sometimes motivated by protectionism, they are legitimate measures under the rules of the World Trade Organization (WTO). Thus, the best way to deal with them is to be well prepared for dumping investigations with clear documentation of non-dumping evidence. As the costs of defending antidumping charges tend to be too high for individual farmers (especially small-scale farmers), governments or producers associations are usually needed to facilitate coordinated actions against antidumping charges (Cai and Leung, 2006). As the countervailing tariffs tend to be prohibitive for exporters found guilty of antidumping and seriously disrupt the industry, governments may consider adopting voluntary export restraining measures to avoid being subject to antidumping disputes.[32]

Market standards

Market standards are another major barrier in the international seafood trade. Lack of ability to adhere to food safety and quality requirements is a major barrier for developing countries to access developed countries' import markets (FAO, 2009). Public food safety standards for seafood imports to developed countries are usually stringent, and their violation tends to be very costly.[33] In addition, large retail and restaurant chains with dominating market power would also like to impose private environmental and social standards (concerning animal welfare, child labour, human rights, etc.) on their procurements, the compliance costs of which are often cumbersome or prohibitive for small-scale (or even large yet unorganized) farmers who lack capital and economy of scale (FAO, 2006). Transparency, information sharing (e.g. through e-commerce), and common customs procedures and operations among trading partners have been suggested as means to reduce compliance costs (FAO, 2006).

The rampant emergence of various private product standards and market requirements has led to several controversial issues.[34] One concern is that private market standards may become anticompetitive trade barriers used by

[32] For example, to avoid being subject to serious trade barriers against its salmon exports, the Norwegian Government used feed quota and restriction of issuing new licenses to restrain expansion of the domestic salmon industry (Asche, 1997).

[33] For example, after detection of chloramphenicol residuals, shrimp exports to the European Union (EU) market from China were banned for two years in the early 2000s (Cai and Leung, 2006). After the detection of nitrofuran in some of its shrimp exports to the EU in 2009, the Government of Bangladesh voluntarily halted its shrimp exports to the EU for six months as a precautionary measure against potentially more severe sanctions (GLOBEFISH Highlights, 2010).

[34] It was estimated that there were around 400 seafood-related certification schemes; and the number is rising (FAO, 2009).

companies with significant market power to impose lower prices throughout the supply chain (FAO, 2007b). Market standards initiated by private companies are often viewed by producers and exporting countries as unjustified (i.e. being inconsistent with public standards), unnecessary (i.e. being duplications of standards competently imposed by exporting countries),[35] unfair (i.e. being inconsistently and discriminatorily applied to different suppliers) and uneconomical (i.e. required third-party certification being expensive with little value added). But proponents claim that private standards are useful because public standards tend to be insufficient and incompetently implemented. While market standards initiated by governments can be challenged in the WTO, there are no proper authorities to regulate private standards. In addition, the roles of and boundaries between public and private standards are generally undefined (FAO, 2009).

Regarding the confusing state of market standards in seafood trade,[36] further research is needed to examine the impacts of market standards on both importing and exporting countries and to assess the costs and benefits of their implementation and compliance and the impacts on various stakeholders (FAO, 2007b).

Public interventions in aquaculture production

Property rights

Property rights are established in aquaculture through leases, licenses, permits, concessions or authorizations. The tenures of aquaculture leases are usually long (more than 10 years) and renewable or sometimes indefinite (e.g. in Chile), which is good for fostering long-term behaviours. There are usually user fees associated with aquaculture leases, which sometimes are not large enough to reflect the opportunity costs of land being used (e.g. in the Philippines) and hence provide no incentives for intensification. There are usually restrictions (e.g. over farm size, ownership transfer, foreign ownership) or requirements (e.g. EIA, environmental licenses, project plans) associated with aquaculture leases for the purpose of preventing monopolization or protecting the environment. While such restrictions tend to impose constraints on fish farmers' operations, there seems to be ways to circumvent them.37 The bureaucratic processes of

[35] While countries with a developed aquaculture sector (e.g. Thailand) may have well-established objectives and institutions to enforce food safety standards, newcomers (e.g. Myanmar) tend to be underdeveloped in this respect (Hishamunda *et al.*, 2009).

[36] Studies found that shortcomings of existing market standards in seafood trade include "limited openness in governance of standards and insufficient multi-stakeholder participation in their development; few meaningful, measurable and verifiable criteria addressing the key areas of concern; insufficient independence in the operations of the bodies responsible for creating, holding, inspecting and certifying standards; frequent absence of effective mechanisms for applying corrective measures and sanction procedures as well as a deficient certification of the chain of custody." (FAO, 2009, p. 100).

[37] For example, fish farmers in the Philippines have relatives apply for adjacent lands in order to neutralize the land size restriction and gain economy of scale, and foreign investors sometimes use local people as "fronts" to bypass the regulation that at least 60 percent of the farm ownership must belong to Philippine nationals (Hishamunda *et al*., 2009).

granting aquaculture permits, which used to be time consuming and inefficient, have been greatly improved in most countries (Hishamunda *et al*., 2009.

The case of Myanmar is unique and worth noting. As a newcomer in aquaculture, the country sets no restrictions over area and size for aquaculture but allows only short periods (up to three years) for aquaculture operations other than pond culture (Hishamunda *et al.,* 2009). The freedom over area and size is attractive to large-scale farming investors because it allows them to have economies of scale, but the short period of tenure (albeit with possibility of renewal) and other restrictions and requirements associated with the lease (e.g. water surface area must occupy no less than three quarters of the leased land; the farm must be operational in three years and fully operational in five years) may foster short-term behaviours. It remains to be seen whether such a unique institutional arrangement can help the country achieve rapid aquaculture development in the short run without long-term problems.

Seed production

Seed production is a crucial stage of aquaculture operations; breakthroughs in aquaculture were often triggered by availability of abundant and high-quality seed. Asian countries' experiences indicate that proper public-private partnership is an important factor for facilitating seed industry development in aquaculture (Hishamunda *et al.,* 2009). In Asia, public hatcheries were initially established to supply fry and fingerlings and demonstrate hatchery technologies, and when private hatcheries became developed, public hatcheries were usually either privatized or focused on species underprovided by the private sector. However, as non-profit organizations, public hatcheries may disrupt the seed market by supplying low-priced or poor-quality seed; and they sometimes are associated with corruption. Public support for development of private hatcheries (e.g. tax exemptions, subsidies, access to credits, technical assistance, providing high-quality bloodstocks, organizing seed markets) have proven to be a better alternative for the development of the seed industry in aquaculture. For the purposes of maintaining seed supply and quality and preventing diseases, seed production and trade have been under stricter public regulations (e.g. licensing, certification, International Organization for Standards (ISO) standards), which sometimes have negative impacts on seed producers' profitability.[38]

Feed production

Feed production is a lucrative business in aquaculture because feed costs usually account for a major part of production costs (especially in intensive aquaculture operations). In Asia, the importance of feed supply in aquaculture operations and the shortage of feed ingredients have led to increasing public supports to the industry (Hishamunda *et al.,* 2009), while in Latin America,

[38] For example, the Philippines' ban of exporting milkfish and shrimp seed deprived hatchery operators of the opportunities to take advantage of seasonal demands from abroad (Hishamunda *et al.*, 2009).

where feed ingredients are abundant, aquaculture feed production is dictated mainly by market forces, with public regulation of permissible feed ingredients for environmental protection or food safety purposes.[39] Shortage of aquaculture feed ingredients (fishmeal and fish oil) and consequential increases in their prices have become a major and increasing challenge to sustainable aquaculture development,[40] especially in regions that heavily rely on imported fishmeal and fish oil (e.g. Asia). In the short run, tariff reductions or exemptions on imported feed or feed ingredients have been applied to help mitigate the negative impacts of rising feed prices on fish farmers (Hishamunda *et al.,* 2009), while in the long run, proactive public support is called for to help find other cost-effective feed ingredients and to increase the productivity of feed production through promoting large-scale feed mills and encouraging foreign investments (Hishamunda, Poulin and Ridler, 2009).[41]

Financial capital

Financial capital has been a major bottleneck for aquaculture development.[42] The risky nature of aquaculture and incomplete understanding of the business by investors, creditors and insurance companies are two major factors deterring investments in aquaculture. While credits from feed or seed producers are sometimes available to finance fish farmers' daily operations, start-up funds for infrastructure construction and other capital investments are more difficult to obtain, especially for small-scale farmers who lack the resources and skills needed to satisfy banks' collateral and documentation requirements. Various public supports (e.g. encouraging banks to lend to small farms, providing financial supports to farmers' cooperatives, public-initiated loan programmes, interest rate subsidies, tax breaks) have been applied in Asia to help small-scale farmers access credits and reduce their financial burdens. Experience indicates that government agencies usually lack expertise and incentives to allocate public funds effectively and efficiently; public credit programmes tend to benefit large borrowers instead of helping the poor, and repayment performances are usually poor (Hishamunda *et al.,* 2009).

Foreign direct investments

Foreign direct investments (FDI) are a popular way for underdeveloped sectors to overcome financial constraints because foreign investors tend to bring not

[39] For example, only residuals from food processing or species not suitable for direct human consumption are allowed to be used to produce aquaculture feed in Ecuador; fresh crustaceans (except *Artemia*) are not allowed to be used in feed production in Mexico; and use of animal meat is not allowed in aquaculture feed production in Chile (Agüero, Hishamunda and Valderrama, 2009).

[40] The prices of fishmeal and fish oil increased dramatically in the mid 2000s because of reduced supply and buoyant demand from China. While the prices stabilized afterwards, they have been rising strongly since 2009 (GLOBEFISH Highlights, 2010).

[41] For example, leftovers from fish processing (e.g. canned tuna and surimi) has been used as ingredients in Thailand to produce fishmeal that has better quality than trash fish from capture.

[42] In a recent survey, experts in all regions except Eastern Europe deemed lack of capital a major challenge to aquaculture development in their respective regions (Hishamunda, Poulin and Ridler, 2009).

only capital but also other side benefits (e.g. technical know-how, management expertise, market access). While there are favourable policies (e.g. tax and tariff exemptions, guarantee of repatriation of profits) to encourage foreign investments in aquaculture, there are also restricting policies (e.g. upper limit of foreign ownership in aquaculture operations) intended to prevent them from being dominant. For countries (e.g. in sub-Saharan Africa) that possess abundant natural resources but lack human and financial resources as well as the proper institutions to realize their potentials in aquaculture, foreign investments have a great potential to provide the first push that helps the sector overcome various constraints and start in the growing track. Further research on how foreign investments may help aquaculture development in Africa is warranted.

Technology and know-how

Technology and know-how tend to be underprovided in the aquaculture sector because farmers usually lack resources and incentives to undertake aquaculture research that would benefit the entire sector. While protection of intellectual property rights (IPRs) (through patents, trademarks, copyrights, etc.) can motivate technological innovations in aquaculture (Ninan *et al.,* 2005), there have been controversies over the extent of private IPRs (e.g. whether genetically modified organisms (GMOs) are allowed to be patented), and the social benefits and costs of private IPRs in aquaculture are generally unclear (Dunham *et al.,* 2001; Beardmore and Porter, 2003).

Public supports are often needed to facilitate technology advancement in aquaculture. However, to be relevant, public-funded research needs to be guided by industry needs. Thus, proper public-private partnership is crucial for fruitful technological advances in aquaculture. In Asia, there are usually specific government agencies responsible for research and technological development in aquaculture; and fish stations, one-stop aqua shops (OAS) or other kinds of service centers were established to provide seed and other materials, training and extension, technical assistance, information about prices and policies, etc. International agencies, non-governmental organizations (NGOs) and farmers associations have also initiated many programmes for capacity building and technology transfers in aquaculture (World Bank, 2006; Hishamunda *et al.,* 2009).[43] However, lack of capacity in government personnel to conduct extension services and in recipients to assimilate technical assistance are still major obstacles preventing technological advances in aquaculture from benefiting more fish farmers.

[43] Examples include the genetically improved farmed tilapia (GIFT) financed by the Asian Development Bank (ADB), the International Network on Genetics in Aquaculture (INGA) developed by the WorldFish Center, the STREAM (Support to Regional Aquatic Resources Management) Initiatives sponsored by NACA, and the Consortium on Shrimp Aquaculture and the Environment sponsored by multiple agencies including FAO, NACA, the World Bank, the World Wide Fund for Nature (WWF) and the United Nations Environment Programme (UNEP) (World Bank, 2006).

In some regions such as Latin America, there are few technical programmes available for training mid-level aquaculture employees (e.g. farm coordinators, laboratory assistants, specialized processing plant staff), and participation in sporadically offered extension courses is often not merit-based but decided based on political, family or other connections.

Experience in Asian countries indicates that corporate approaches (e.g. contract farming and the nucleus-estate model) tend to be effective ways for technical transfer (World Bank, 2006).[44] Foreign direct investments also tend to promote capacity building and technical transfers, but their impacts in this respect are less well documented.

Institutional arrangements for socially acceptable aquaculture

In addition to environmental responsibility and economic viability, a socially acceptable aquaculture sector also entails the benefits and costs of aquaculture development being equitably distributed among various stakeholders. As many constraints hinder less-advantaged groups from enjoying the benefits of aquaculture development, pro-poor aquaculture entails significant institutional supports from governments, international agencies, NGOs, farmers associations and other organizations that promote pro-poor aquaculture.

Public policies

As discussed above, in most aquaculture countries there are public policies and regulations established to protect the interests of less advantaged stakeholders in aquaculture development. However, well-intended public policies do not necessarily achieve desirable effects.

In a recent survey, the absence of appropriate policies for aquaculture development was identified by experts as the most important factor hindering aquaculture development in Africa. According to the experts, aquaculture development policies in Africa have overemphasized promotion of small-scale aquaculture as a rural livelihood means but overlooked the potentials of commercial aquaculture in promoting economic growth, which resulted in an underdeveloped aquaculture sector predominated by government or donor-driven investments as opposed to commercially oriented private ventures (Hishamunda, Poulin and Ridler, 2009). Similarly, the experience of Latin American countries indicates that private initiatives backed up by significant institutional supports tend to facilitate aquaculture development, while over intervention ("duplication of effort") and overregulation ("excess of rules and powers") by authorities would hamper the progress (FAO, 2006). Asian countries' experiences also indicate that commercial aquaculture (the "transition pathway" and the "consolidation pathway") tends to be more effective in poverty alleviation than subsistence aquaculture (the "static model") (World Bank, 2006, p. 44).

[44] See footnote 16 for information about the nucleus-estate model.

An important message conveyed by these experiences is that pro-poor public policies should focus on enabling the poor to participate in aquaculture business instead of attempting to shield them against competition. Thus, restrictive public policies and regulations (e.g. limiting farm size) intended to protect less-advantaged farmers should be applied cautiously, and their impacts should be monitored and assessed comprehensively. Instead of directly subsidizing aquaculture activities deemed pro-poor, governments and international agencies should focus on creating an enabling business environment through infrastructure construction, capacity building, technology innovations and other public goods that tend to be underprovided by the private sector.

Non-governmental Organizations

NGOs that commit to be guardians of the poor have contributed greatly to pro-poor aquaculture by providing training and extension services, facilitating research and technological innovations, developing standards and codes of conduct, organizing farmers, promoting BMPs, participating in public policy decision-making, monitoring public programmes and private businesses, educating consumers and increasing public awareness of development issues in aquaculture (Bostick, 2008).

As non-profit and mission-driven organizations, NGOs can be less bureaucratic than government agencies but more dedicated, flexible and efficient in pursuing their social objectives and representing their constituencies. However, lack of clear principal-agent relationships between NGOs and their constituencies may result in inconsistent advocacies. For example, some NGOs endorse the notion that farming high-value carnivorous species should be discouraged because of its bio-inefficiency (e.g. Allsopp, Johnston and Santillo, 2008), but they sometimes do not pay enough attention to the fact that farming high-value species with great market potentials can be more effective in leading poor farmers out of the poverty trap, even though pro-poor is one of their objectives.

Aquaculture's socio-economic impacts are complex and involve many tradeoffs, but advocacy groups that dislike ambivalence sometimes choose to focus on the negative side of aquaculture. While such approaches are effective in drawing public attention to specific issues, they are nevertheless insufficient for policy recommendations that require more balanced assessment of the tradeoffs of aquaculture's complex socio-economic impacts. In addition, unbalanced focus on aquaculture's negative impacts would tend to antagonize the industry and take a toll on its public image.[45]

[45] According to a recent survey, aquaculture experts in all regions but Eastern Europe identified the negative public images of and public opposition to aquaculture as major challenges to aquaculture development (Hishamunda, Poulin and Ridler, 2009). Commercial aquaculture is sometimes perceived as a profit-seeking, environment-degrading, drug-using and animal-abusing business that serves the appetite of the rich for food and money. While such unpleasant public images reflect the fact that imprudent or irresponsible aquaculture development would tend to cause negative socio-economic impacts, they mainly represent widespread public misperception and mistrust of the industry, which has been fostered or exacerbated by sensationalist media coverage of aquaculture.

NGOs have become increasingly influential in the aquaculture sector through certification programmes (e.g. ecolabelling) and other schemes that gather the attention and supports of consumers and hence allow them to use market forces to influence private businesses.[46] More power should be associated with more responsibility. Further research on the role of NGOs in aquaculture is warranted.

Community-based aquaculture

Being organized can help farmers gain access to markets, credits and technologies; share experiences, information and risks; enforce codes of conduct; promote BMPs; increase bargaining power; and enhance community cohesion, among others. While there are examples that community or cluster-based aquaculture can be an effective way to empower less advantaged stakeholders (Umesh *et al.,* 2010), the success of such institutional arrangements requires a cooperation mindset, organizational capacity and coordination mechanisms that rural farmers may be lacking (Radheyshyam, 2001; De and Saha, 2005).[47]

While community-based aquaculture has mainly been a tool used by donors and NGOs to promote pro-poor aquaculture (World Bank, 2006), it has potential to become a self-sustained institutional arrangement for facilitating socially responsible aquaculture.[48] Further study on how community-based aquaculture can help develop social capital and how public policies and NGOs can facilitate this process is warranted.

Co-management

As aquaculture's complex socio-economic impacts involve many tradeoffs, command and control measures of policy decision-making are not likely to result in socially acceptable aquaculture development and may not even be feasible because assessment of socio-economic impacts of aquaculture is a difficult process that requires involvement of various stakeholders.[49] Thus, co-management, which is a decentralized decision-making process intended to share rights and duties among all stakeholders, has become increasingly popular in aquaculture management (FAO, 2006).

---

[46] While the aquaculture industry used to view NGOs as nuisances, many seafood retailers and processors have now chosen to collaborate with NGOs in enforcing market standards that promote sustainable aquaculture (Sigg, 2007; Bostick, 2008).

[47] For example, a case study in India indicated that community-based aquaculture is subject to constraints of conflicts in distribution of benefits, lack of proper leadership, lack of cooperative and democratic atmosphere, lack of proper mechanisms to allocate rights, lack of technical skills and lack of protection of the poor (De and Saha, 2005).

[48] For example, the experience of a cluster-based shrimp farming project in India indicates that group farming helped cluster farmers improve social responsibilities by information sharing; cooperation in infrastructure construction, seed selection and other activities; coordination in stocking timing and disease remedial actions, etc. (Umesh *et al.*, 2010).

[49] While the economic impacts of aquaculture development can be evaluated by monetary values based on methods such as costs and benefits analysis, social impacts (most of which are intangible) and the tradeoffs of various impacts are difficult to measure reliably by money-metric measures and hence require a more participatory approach such as the multiple criteria decision-making (MCDM) framework (e.g. the Analytical Hierarchy Process (AHP) method) (FAO, 2008b).

At the macro level, civil societies (including NGOs and producers associations) have played increasingly active roles in policy decision-making regarding resource management, capacity building, poverty alleviation, empowerment of disadvantaged groups, etc., which tends to result in more realistic and effective policies and improved implementation (FAO, 2006). At the micro level, partnerships between producers associations and scientific communities (EIFAC, 2006), between NGOs and the private industry (Bostick, 2008) and between individual fish farmers (through community-based aquaculture) have become increasingly widespread and beneficial.[50] Institutional platforms such as the Aquaculture Dialogues initiated by the World Wide Fund for Nature (WWF) have been increasingly used to facilitate communication among stakeholders.

While co-management is a promising institutional arrangement for facilitating socially responsible aquaculture, it is still at the early stage of development and yet to become mainstream. A matured co-management framework would require not only governments' endorsement but also adjustments by all stakeholders. For example, NGOs may need to consider whether to pursue more focused social objectives and represent more specific constituencies so as to increase their efficacy in the participatory decision-making process. While co-management has thus far mainly been motivated by practical needs, further systematic research would be useful to provide insights about this institutional arrangement that has potential to help eventually achieve the goal of environmentally responsible, economically viable and socially acceptable aquaculture.

Conclusions

The above discussion has reviewed the socio-economic impacts of aquaculture based on the existing literature on the global experience of aquaculture development in the new millennium. While effort has been exerted to provide a balanced review of aquaculture's socio-economic impacts, some equally important issues may not be discussed sufficiently due to limitation of the paper's space and the authors' knowledge. While evidence indicates that aquaculture development in the new millennium has been impressive and moved towards the goal set a decade ago in the Bangkok Declaration (i.e. being environmentally responsible, economically viable and socially acceptable), more systematic and comprehensive assessment based on quantitative measures is needed to assess the extent to which the goals of the Bangkok Declaration have been achieved.[51]

[50] For example, the Canadian Alliance for Aquaculture Reform (CAAR), an NGO association, has signed a memorandum (Framework for Dialogue) with Marine Harvest Canada (MHC) under which MHC agreed to exert efforts to reduce the environmental impacts of its operations while CAAR agreed not to target MHC in their campaigns (Bostick, 2008).

[51] While indicators are useful tools for evaluating aquaculture's socio-economic contributions (e.g. Wattage, 2010), assessment of aquaculture's socio-economic impacts and their tradeoffs is an important yet difficult topic that entails further research effort (FAO, 2008b).

Despite the achievements, sustainable aquaculture development in the future faces many challenges such as more stringent environmental protection requirements, higher food safety standards, lack of aquaculture sites, shortage of feed and increasing energy prices, among others. Enabling public policies, more efficient regulatory frameworks, better partnerships among stakeholders, as well as other improvements in institutional arrangements are needed for aquaculture to overcome these constraints and continue developing into a mature and established industry.

References

Ababouch, L. 2007. Safety of aquaculture products: consumer protection, international regulatory requirements and traceability. *In* R. Arthur & J. Nierentz, eds. *Global Trade Conference on Aquaculture. Qingdao, China, 29–31 May 2007,* pp. 77–86. FAO Fisheries Proceedings No. 9. Rome, FAO.

Acosta, B.O. & Gupta, M.V. 2010. The Genetic Improvement of Farmed Tilapias Project: impact and lessons learned. *In* S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture,* pp. 149–171. Chapter 8. New York, Springer.

Ahmed, M. & Lorica, M.H. 2002. Improving developing country food security through aquaculture development – lessons from Asia. *Food Policy*, 27: 125–141.

Anderson, J.L. 2007. Aquaculture and fisheries: complement or competition. *In* R. Arthur & J. Nierentz, eds. *Global Trade Conference on Aquaculture. Qingdao, China, 29–31 May 2007*, pp. 231–236. FAO Fisheries Proceedings No. 9. Rome, FAO.

APEC/FAO/NACA/SEMARNAP. 2001. *Trans-boundary aquatic animal pathogen transfer and the development of harmonized standards on aquaculture health management.* Report of the joint APEC/FAO/NACA/SEMARNAP Workshop, Puerto Vallarta, Jalisco, Mexico, 24–28 July 2000. Bangkok, Network of Aquaculture Centres in Asia-Pacific.

Allsopp, M., Johnston, P. & Santillo, D. 2008. *Challenging the aquaculture industry on sustainability,* 2nd Edn. 22 pp. Amsterdam, Greenpeace.

Arengo, E., Diaz, E., Ridler, N. & Hersoug, B. 2010. *State of information on social impacts of salmon farming: a report by the Technical Working Group of the Salmon Aquaculture Dialogue.* 91 pp. World Wide Fund for Nature.

Arthur, J.R., Bondad-Reantaso, M.G., Campbell, M., Hewitt, C.L., Phillips, M.J. & Subasinghe, R.P. 2009. *Understanding and applying risk analysis in aquaculture production: a manual for decision-makers.* FAO Fisheries and Aquaculture Technical Paper No. 519/1. Rome, FAO. 113 pp.

Arthur, R. & Nierentz, J. (eds.) 2007. *Global Trade Conference on Aquaculture. Qingdao, China, 29–31 May 2007.* FAO Fisheries Proceedings No. 9. Rome, FAO. 271 pp.

Asche, F. 1997. Trade disputes and productivity gains: the curse of farmed salmon production. *Marine Resource Economics,* 12: 67–73.

Bai, S.C. 2008. The Republic of Korea. *In* A. Lovatelli, M.J. Phillips, J.R. Arthur & K. Yamamoto, eds. *FAO/NACA Regional Workshop on the Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region. Guangzhou, China, 7–11March 2006*, pp. 199–206. FAO Fisheries Proceedings. No. 11. Rome, FAO.

Barbier, E.B. & Cox, M. 2004. An economic analysis of shrimp farm expansion and mangrove conversion in Thailand. *Land Economics,* 80: 389–407.

Barraclough, S. & Finger-Stich, A. 1996. *Some ecological and social implications of commercial shrimp farming in Asia.* UNRISD Discussion Paper 74, 62 pp. Geneva, United Nations Research Institute for Social Development.

Barrionuevo, A. 2008. *Salmon virus indicts Chile's fishing methods.* New York Times, March 27, 2008. (available at: www.nytimes.com/2008/03/27/world/americas/27salmon.html?_r=2&pagewanted=1).

Be, T.T., Dung, L.C. & Brennan, D. 1999. Environmental costs of shrimp culture in the rice growing regions of the Mekong Delta. *Aquaculture Economics & Management*, 3: 31–42.

Beardmore, J.A. & Porter, J.S. 2003. *Genetically modified organisms and aquaculture*. FAO Fisheries Circular No. 989. Rome, FAO. 35 pp.

Bhat, M. G. & Bhatta, R. 2004. Considering aquacultural externality in coastal land allocation decisions in India, *Environmental and Resource Economics*, 29 (1): 1 – 20.

Bostick, K. 2008. NGO approaches to minimizing the impacts of aquaculture: a review. *In* M. Homer, K, Black, C.M. Duate, N. Marba & I. Karakassis, eds. *Aquaculture in the ecosystem,* pp. 227-250. Chapter 7. Springer, Dordrecht, Netherlands

Brugere, C. & Kusakabe, K. 2001. *Women in aquaculture.* Project FWG 03/99. Final Report. Singapore, Asia Pacific Economic Cooperation. 60pp.

Brugere, C., McAndrew, K. & Bulcock, P. 2001. Does cage aquaculture address gender goals in development? Results of a case study in Bangladesh. *Aquaculture Economics and Management,* 5(3/4): 179–189.

Brugere, C. 2006. A review of the development of integrated irrigation-aquaculture (IIA), with special reference to West Africa. In: M. Halwart and A.A. van Dam (Eds) Integrated Irrigation and Aquaculture in West Africa: Concepts, Practices and Potential, pp. 27-60. FAO, Rome.

Cai, J. & Leung, P. 2006. An overview of China's shrimp industry. *In* P. Leung & C. Engle, eds. *Shrimp culture: economics, market and trade*, pp. 197–221. Chapter 14. Ames, Blackwell Publishing.

Cai, J. & Leung, P. 2007. A review of comparative advantage assessment approaches in relation to aquaculture development. *In* P. Leung, C.-S. Lee & P.S. O'Bryen. *Species and system selection for sustainable aquaculture,* pp. 43–56. Chapter 4. Ames. Blackwell Publishing.

Cai, J., Leung, P. & Hishamunda, N. 2009. *Assessment of comparative advantage in aquaculture: framework and application on selected species in developing countries.* FAO Fisheries and Aquaculture Technical Paper No. 528. Rome, FAO. 73 pp.

Cruz-Torres, L.M. 2000. Pink gold rush: shrimp aquaculture, sustainable development, and the environment in northwestern Mexico. *Journal of Political Ecology*, 7: 63–90.

De Silva, S.S. & Davy, F.B. 2010. Aquaculture successes in Asia: contributing to sustained development and poverty alleviation. *In* S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture,* pp. 1–14. Chapter 1. New York, Springer.

De, H.K. & Saha, G.S. 2005. Community based aquaculture – issues and challenges. *Aquaculture Asia,* 10 (4): 8–9.

Dunham, R.A., Majumdar, K., Hallerman, E., Bartley, D., Mair, G., Hulata, G., Liu, Z., Pongthana, N., Bakos, J., Penman, D., Gupta, M., Rothlisberg, P. & Hoerstgen-Schwark, G. 2001. Review of the status of aquaculture genetics. *In* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. *Aquaculture in the third millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20–25 February 2000,* pp. 137–166. Bangkok, NACA and Rome, FAO.

EIFAC. 2006. *Report and proceedings of the EIFAC Symposium on Aquaculture Development – Partnership between Science and Producers Associations. Wierzba, Poland, 26–29 May 2004, held in connection with the European Inland Fisheries Advisory Commission, twenty-third session. Wierzba, Poland, 26 May–2 June 2004*. EIFAC Occasional Paper No. 37. Rome, FAO. 136 pp.

Erondu, E.S. & Anyanwu, P.E. 2005. Potential hazards and risks associated with the aquaculture industry. *African Journal of Biotechnology,* 4(13): 1622–1627.

FAO. 1989. *Sustainable development and natural resources management.* Conference. Food and Agriculture Organization of the United Nations, Rome. C 89/2 – Supplement 2. August 1989, 54 pp.

FAO. 1995. *Code of conduct for responsible fisheries.* Rome, FAO. 41 pp.

FAO. 1997. *Review of the state of world aquaculture.* FAO Fisheries Circular No. 886, Rev.1. Rome, FAO. 163 pp.

FAO. 2005. *Impact of HIV/AIDS on fishing communities: policies to support livelihoods, rural development and public health*. New Directions in Fisheries: A Series of Policy Briefs on Development Issues, No. 2. Rome, FAO. 12 pp.

FAO. 2006. *The State of world aquaculture 2006.* FAO Fisheries Technical Paper No. 500. Rome, FAO. 134 pp.

FAO. 2007a. *Report of the FAO Expert Workshop on the Use of Wild Fish and/or Other Aquatic Species as Feed in Aquaculture and its Implications to Food Security and Poverty Alleviation. Kochi, India, 16–18 November 2007.* FAO Fisheries Report No. 867. Rome, FAO. 29 pp.

FAO. 2007b. *The state of world fisheries and aquaculture 2006.* FAO Fisheries and Aquaculture Department, Rome, FAO.162 pp.

FAO. 2008. *Report of the Expert Consultation on the Assessment of Socio-economic Impacts of Aquaculture. Ankara, Turkey, 4–8 February 2008.* FAO Fisheries Report No. 861. Rome, FAO. 53 pp.

FAO. 2009. *The state of world fisheries and aquaculture 2008*. FAO Fisheries and Aquaculture Department, Rome, FAO. 176 pp.

FAO/NACA/WHO, 1999. Food safety issues associated with products from aquaculture: report of a joint FAO/NACA/WHO study group. WHO Technical Report Series 883. World Health Organization, Geneva. 55 pp.

Flaherty, M., Vandergeest, P. & Miller, P. 1999. Rice paddy or shrimp pond: tough decisions in rural Thailand. *World Development,* 27(12): 2045–2060.

GLOBEFISH Highlights, 2009. FAO/GLOBEFISH Highlights. Issue 3/2009. Rome, FAO. 31 pp.

GLOBEFISH Highlights. 2010. FAO/GLOBEFISH Highlights. Issue 2/2010 Rome, FAO. 31 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution). 1991. *Reducing environmental impacts of coastal aquaculture.* GESAMP Reports and Studies No. 47. Rome, FAO. 35 pp.

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D. Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. & Toulmin, C. 2010. Food security: the challenge of feeding 9 billion people. *Science,* 327: 812–818.

Gurung, T.B., Mulmi, R.M., Kalyan, K.C., Wagle, G., Pradhan, G.B., Upadhayaya, K. & Rai, A.K. 2010. Cage fish culture: an alternative livelihood option for communities displaced by reservoir impoundment in Kulekhani, Nepal. *In* S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture,* pp. 85–102. Chapter 5. New York, Springer.

Hasan, M.R. 2001. Nutrition and feeding for sustainable aquaculture development in the third millennium. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 193-219. NACA, Bangkok and FAO, Rome.

Hasan, M.R. & Halwart, M. (eds.) 2009. *Fish as feed inputs for aquaculture: practices, sustainability and implications.* FAO Fisheries and Aquaculture Technical Paper No. 518. Rome, FAO. 407 pp.

Hasan, M.R., Hecht, T., De Silva, S.S. & Tacon, A.G.J. (eds.) 2007. *Study and analysis of feeds and fertilizers for sustainable aquaculture development.* FAO Fisheries Technical Paper No. 497. Rome, FAO. 510 pp.

Hishamunda, N., Bueno, P.B., Ridler, N. & Yap, W.G. 2009. *Analysis of aquaculture development in Southeast Asia: a policy perspective.* FAO Fisheries and Aquaculture Technical Paper No. 509. Rome, FAO. 69 pp.

Hishamunda, N., Cai, J. & Leung, P. 2009. *Commercial aquaculture and economic growth, poverty alleviation and food security: assessment framework.* FAO Fisheries and Aquaculture Technical Paper No. 512. 93 Rome, FAO. pp.

Hishamunda, N., Poulain, F. & Ridler, N. 2009. *Prospective analysis of aquaculture development: the Delphi method.* FAO Fisheries and Aquaculture Technical Paper No. 521. Rome, FAO. 93 pp.

Howgate, P.C., dos Santos, C.L. & Shehadeh, Z.H. 1997. Safety of food products from aquaculture. In: Review of the State of World Aquaculture. FAO Fisheries Circular. No. 886, Rev.1. Rome, FAO. 163 pp.

IISD. 2004. *An environmental impact assessment of China's WTO accession: an analysis of six sectors.* A report by the Task Force on WTO and Environment China Council for International Cooperation on Environment and Development. October 2004. Winnipeg, International Institute for Sustainable Development, 206 pp.

Irz, X., Stevenson, J.R., Tanoy, A., Villarante, V. & Morissens, P. 2007. The equity and poverty impacts of aquaculture: insights from the Philippines. *Development Policy Review,* 25: 495–516.

Jenkins, S., Smith, P.T., Tookwinas, S. & Phillips, M.J. 1999. An assessment of the status of the shrimp farming industry in Thailand. *In* P.T. Smith, ed. *Coastal shrimp aquaculture in Thailand: key issues for research,* pp. 14–68. ACIAR Technical Reports No. 7. Canberra, Australian Center for International Agriculture Research.

Karim, M., Ahmed, M., Talukder, R.K., Taslim, M.A. & Rahman, H.Z. 2006. *Dynamic agribusiness-focused aquaculture for poverty reduction and economic growth in Bangladesh.* Policy Working Paper, WorldFish Center Discussion Series No. 1. 38 pp.

Kawarazuka, N. & Béné, C. 2010. Linking small-scale fisheries and aquaculture to household nutritional security: a review of the literature. *Food Security*, 2(4): 343–357.

Kawarazuka, N. & Béné, C. 2011. The potential role of small fish in improving micronutrient deficiencies in developing countries: building the evidence. *Public Health Nutrition*, 14 (11): 1927-38. Kongkeo, H. & Davy, F.B. 2010. Backyard hatcheries and small scale shrimp and prawn farming in Thailand. *In* S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture,* pp. 67–83. Chapter 4. New York, Springer.

Lewins, R. 2006. *Coastal aquaculture and development-planning for sustainability.* Centre for Environment and Society Occasional Paper 2006-4. Colchester, University of Essex. 22 pp.

Li, J. 2007. Developing sustainable aquaculture industry and building a harmonious international trade order. *In* R. Arthur & J. Nierentz, eds. *Global Trade Conference on Aquaculture. Qingdao, China, 29–31 May 2007*, pp. 29–34. FAO Fisheries Proceedings No. 9. Rome, FAO.

Lovatelli, A., Phillips, M.J., Arthur, J.R. & Yamamoto K. (eds.) 2008. *FAO/NACA Regional Workshop on the Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region. Guangzhou, China, 7–11, March 2006*. FAO Fisheries Proceedings No. 11. Rome, FAO. 325 pp.

Mallison, A. 2007. Aquaculture – what retailers expect from producers. *In* R. Arthur & J. Nierentz, eds. *Global Trade Conference on Aquaculture. Qingdao, China, 29–31 May 2007,* pp. 153–158. FAO Fisheries Proceedings No. 9. Rome, FAO.

Mente, E., Pantazis, P., Neofitou, C., Aifanti, S., Santos, M. B., Oxouzi, E., Bagiatis, V., Papapanagiotou, E., Kourkouta, V. & Soutsas, K. 2007. Socioeconomic interactions of fisheries and aquaculture in Greece: A case study of South Evoikos Gulf. *Aquaculture Economics & Management,* 11(3): 313–334.

Miao, W. 2010. Recent developments in rice-fish culture in China: a holistic approach for livelihood improvement in rural areas. *In* S.S. De Silva & F.B. Davy, eds. *Success stories in Asian aquaculture,* pp. 15–40. Chapter 2. New York, Springer.

Moreau, D.T.R. & Neis, B. 2009 Occupational health and safety hazards in Atlantic Canadian aquaculture: laying the groundwork for prevention. *Marine Policy,* 33(2): 401–411.

NACA, 1994. Impact of shrimp farming on the environment: study 1. Six meeting of the governing council (GCM-6) of NACA, Beijing, China, 162p.

NACA/FAO. 2000. *Aquaculture development beyond 2000: the Bangkok Declaration and Strategy.* Conference on Aquaculture in the Third Millennium, 20–25 February 2000, Bangkok, Thailand. Bangkok, NACA & Rome, FAO. 27 pp.

Naylor, R.L., Goldburg, R.J., Mooney, H., Beveridge, M., Clay, J., Folke, C., Kautsky, N., Lubchenco, J., Primavera, J. & Williams, M. 1998. Nature's subsidies to shrimp and salmon farming. *Science,* 282: 883–884.

Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. & Troell, M. 2000. Effect of aquaculture on world fish supplies. *Nature,* 405: 1017–1024.

Naylor, R.L., Hindar, K., Fleming, I.A., Goldburg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D. & Mangel, M. 2005. Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. *BioScience*, 55(5): 427–437.

Ninan, S., Sharma, A. Ananthan P.S. & Ojha, S.N. 2005. Intellectual property rights in fisheries sector. *Journal of Intellectual Property Rights,* 10: 52–58.

Petr, T. (ed.) *Inland fishery enhancements. Papers presented at the FAO/DFID Expert Consultation on Inland Fishery Enhancements. Dhaka, Bangladesh, 7–11 April 1997.* FAO Fisheries Technical Paper No. 374. Rome, FAO. 463 pp.

Phillips, B., Ward, T. & Chaffee, C. 2003. *Eco-labelling in fisheries: what is it all about?* London, Blackwell Publishing. 196 pp.

Phillips, M., Subasinghe, R., Clausen, J., Yamamoto, K., Mohan, C.V., Padiyar, A. & Funge-Smith, S. 2007. Aquaculture production, certification and trade: challenges and opportunities for the small-scale farmer in Asia. *In* R. Arthur & J. Nierentz, eds. *Global Trade Conference on Aquaculture. Qingdao, China, 29–31 May 2007*, pp. 165–169. FAO Fisheries Proceedings No. 9. Rome, FAO.

Radheyshyam. 2001. Community-based aquaculture in India – strength, weakness, opportunities and threats. Naga, The *ICLARM Quarterly,* 24 (1–2): 9–12.

Rijsberman, F. (ed.) 1999. *Conflict management and consensus building for integrated coastal management in Latin America and the Caribbean.* Technical Paper Series. Inter-American Development Bank, Sustainable Development Department. 51 pp.

Roheim, C.A. 2009. Ecolabelling of fisheries products: assessment of its benefits. *In* H. Einarsson & W. Emerson, eds. *International seafood trade: challenge and opportunities. FAO/University of Akureyri Symposium, 1–2 February 2007, Akureyri, Iceland.* FAO Fisheries and Aquaculture Proceedings 13. Rome, FAO. pp. 85–92.

Sathirathai, S. & Barbier, E.B. 2001. Valuing mangrove conservation in southern Thailand. *Contemporary Economic Policy,* 19: 109–122.

Siggs, M. 2007. Consumer assurance: market-based quality schemes, certification, organic labels, ecolabelling, retailer specifications. *In* R. Arthur & J. Nierentz, eds. *Global Trade Conference on Aquaculture. Qingdao, China, 29–31 May 2007*, pp. 89–102. FAO Fisheries Proceedings No. 9. Rome, FAO. 271 pp.

Smith, M.D., Roheim, C.A., Crowder, L.B., Halpern, B.S., Turnipseed, M., Anderson, J.L., Asche, F., Bourillón, L., Guttormsen, A.G., Khan, A., Liguori, L.A., McNevin, A., O'Connor, M.I., Squires, D., Tyedmers, P., Brownstein, C., Carden, K., Klinger, D.H., Sagarin, R. & Selkoe, K.A. 2010. Sustainability and global seafood. *Science,* 327: 784–786.

STREAM, 2003. Improving coastal livelihoods through sustainable aquaculture practices in Hon Mun marine protected area, Nha Trang Bay, Vietnam: a report to the collaborative APEC Grouper Research and Development Network, a project report in *Improving coastal livelihoods through sustainable aquaculture practices*. Support to Regional Aquatic Resources Management (STREAM), Bangkok Thailand, pp. 151-193.

Tacon, A.G. & Metian, M. 2009. Fishing for feed or fishing for food: increasing global competition for small pelagic forage fish. *Ambio*, 38(6): 294–302.

Tacon, A.G., Metian, M. Turchini, G. & De Silva, S. 2010. Responsible aquaculture and trophic level implications to global fish supply. *Reviews in Fisheries Science,* 18(1): 94–105.

Tisdell, C.A. 2004. Aquaculture, environmental spillovers and sustainable development: links and policy choices. *In* M.A. Quaddus & M.A.B. Siddique, eds. *Handbook of sustainable development planning: studies in modelling and decision support*, pp. 249–268. Cheltenham, Edward Elgar.

Umesh, N.R., Chandra Mohan, A.B., Ravibabu, G., Padiyar, P.A., Phillips, M.J., Mohan, C.V. & Vishnu Bhat, B. 2010. Shrimp farmers in India: empowering small-scale farmers through a cluster-based approach. *In* S.S. De Silva & F.B. Davy, eds. *Success stories in Asian* aquaculture, pp. 41–66. Chapter 3. New York, Springer.

Ward, T. & Phillips, B. (eds.) 2008. *Seafood ecolabelling: principles and practice.* London,Wiley-Blackwell. 472 pp.

Wattage, P. 2010. Millenium Development Goals and aquaculture: indicators to evaluate the conservation of resource base for poverty reduction. *In* M.G. Bondad-Reantaso & M. Prein, eds. *Measuring the contribution of small-scale aquaculture: an assessment*, pp. 59– 72. Fisheries and Aquaculture Technical Paper No. 534. Rome, FAO.

World Bank, 2006. *Aquaculture: changing the face of the waters: meeting the promise and challenge of sustainable aquaculture.* Report No. 36622 – GLB. Washington, D.C. The International Bank for Reconstruction and Development/ The World Bank. 138 pp.