The impact of shrimp farming on mangrove ecosystems

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Review

The impact of shrimp farming on mangrove ecosystems

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Abstract

Farmed shrimp production and value continue to increase with Asia producing the global majority of shrimp and the USA, Japan and Europe being the main importers. Shrimp farming systems are very diverse in their management, size and impacts. There are many causes for mangrove loss but the conversion of mangroves to shrimp farms has caused considerable attention. The major issues of shrimp farming include the loss of important ecological and socio-economic functions of mangrove ecosystems, changes in hydrology, salinization, introduction of non-native species and diseases, pollution from effluents, chemicals and medicines, use of wild fish for feed, capture of wild shrimp seed and loss of livelihoods and social conflicts. Global awareness about the need to reduce the impacts of shrimp farming and the importance of sustainable use of mangrove ecosystems has led to a number of guidelines being published. Policy to position shrimp farms behind mangroves can be effective but also requires good institutional capacity and coordination, effective enforcement, incentives, land tenure and participation of all stakeholders for success. Better management practices have been identified which reduce impacts, increase efficiency and profits. Community-based management using partnerships, stewardships or multilateral cooperation schemes, together with integrated, mixed or mangrove-friendly aquaculture practices and mangrove rehabilitation should also be promoted. Introduction of certification schemes may further ensure environmental sustainability, social equity and food safety of aquaculture products that can benefit both the local communities and the consumer. Further inclusion of local communities and raising awareness with the consumer is required.

Keywords: Shrimp farm, Mangrove ecosystem, Environment, Social, Economy, Management, Aquaculture

Review Methodology: An extensive literature search was carried out of conference proceedings, technical reports and scientific papers. The CAB database was searched for mangrove and shrimp and further information was gained from the Internet and discussion with colleagues from around the world. This report provides an overview of the status of shrimp farming and mangrove ecosystems, the issues and impacts and current developments in management from several perspectives.

Shrimp Farming Production

Shrimp farming originated in Southeast Asia about 600 years ago [1], where for centuries Indonesian farmers raised incidental crops of wild shrimp in tidal fishponds called tambaks. Mangrove areas were chosen because of their naturally abundant supply of shrimp post-larvae and tidal water exchange [2]. The first records show that in 1950, 1000 tonnes of *Penaeus* spp. were farmed in Thailand and 180 tonnes in Bangladesh, Japan and Taiwan were early commercial producers in the 1950s of *Penaeus japonicus* and *Penaeus monodon*, respectively and in 1962, 20 tonnes of *Penaeus merguiensis* were produced in Indonesia and 10 tonnes of *P. monodon* in Vietnam [3]. In South America, Equador pioneered shrimp aquaculture production in 1970 with 50 tonnes of *Litopenaeus vannamei* [3]. Global shrimp production in 1970 was 9022 tonnes but then it escalated rapidly with a current global estimate in 2005 of almost 2.7 million tonnes (Table 1; Figure 1).

Table 1 Global shrimp culture productivity (in tonnes) by region since 1950 [3]

Region	1950	1960	1970	1980	1990	2000	2005
Asia	1325	2963	8972	61 880	576 529	995 520	2 376 161
Africa	0	0	0	0	313	5325	11 191
N&C* America	0	0	0	253	14 309	59 643	117 843
South America	0	0	50	9 764	87 397	96 380	164 187
Oceania	0	0	0	< 0.5	1207	4765	5744
World total	1325	2963	9022	71 897	679 755	1 162 083	2 675 126

*N&C=North and Central.

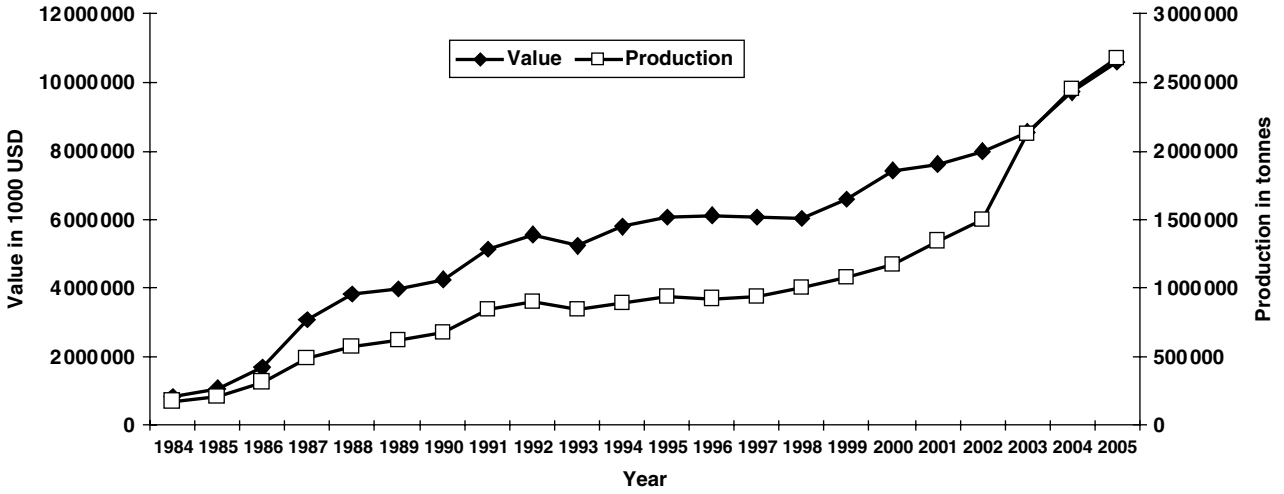

Figure 1 Change in global shrimp aquaculture production and value form 1984 to 2005 [3, 8]

Global shrimp aquaculture production has more than doubled in the past 5 years but productivity varies widely for countries, regions and species year by year [3], mainly because of shrimp viral disease outbreaks and deteriorating environmental conditions [4–7]. Currently the two main species are *L. vannamei* (60%), the Pacific white or whiteleg shrimp native from the west coast of South America and *P. monodon* (27%), the giant or black tiger shrimp native from Asia. Asia still produces the global majority of shrimp at 89% with the principal producing countries now being China, Thailand, Australia, Vietnam and Indonesia [3].

Shrimp Economy

Shrimp aquaculture production represents 4% of the total global aquaculture production but shrimp value is 14% of the total [8]. Shrimp production has increased 3721% since 1980. However, despite the increased supply the total value of shrimp has not declined and the industry in 2005 was worth over $10 billion (Table 2). Only since 2003 has there been a decrease in price of shrimp, the ratio of value against production (Figure 1). The principal exporting countries in 2005 were India, Thailand, Vietnam and Indonesia and the principal importing countries were the USA (25%), Japan (15%) and Spain (9.6%) [8]. There are a number of other associated actors involved in the shrimp industry which add to the value and thus significance of the global shrimp industry. These are the hatchery operators, manufacturers and suppliers of feeds, equipment, chemicals, consultants and businesses dealing with post-harvest handling, processing, distribution, marketing and trade [4, 9]. A large share of the value of shrimp is added within the importing countries by distributors, retailers and food industries [9]. New and domestic markets earnings will also raise estimates of the global retail market of shrimp. Estimates of $50–60 billion have been suggested as the total value of the shrimp market by the time it reaches the consumer [4].

The Food and Agricultural Organization of the United Nations (FAO) provides comprehensive information on global farmed shrimp production compiled from voluntary country data but the reports are two years after the date and the most recent information is for 2005 [3, 8]. GLOBEFISH, a unit of FAO, produces almost monthly shrimp market reports [10]. The Global Aquaculture Alliance (GAA) and Shrimp News International also release current and projected data on world shrimp farming [11, 12]. There are some discrepancies in figures and it is difficult to compile a complete picture for the total diverse shrimp industry economy. However, the

Table 2 Global shrimp value (in $1000) by region since 1984 [8]

Region	1984	1990	2000	2005
Asia	586 703	3 738 233	6 384 109	9 188 027
Africa	11.8	2578	30 673	78 162
N&C* America	15 307	87 991	346 485	497 521
South America	248 071	389 718	632 578	781 429
Oceania	657.8	11 501	43 258	59 888
World total	850 751	4 230 021	7 437 103	10 605 027

*N&C=North and Central.

general consensus for 2006 and 2007 is that although shrimp prices are not as high as in previous years, and there are concerns over product quality and increasing costs in production, production is still profitable and is expanding almost everywhere.

Shrimp Farming Systems

Shrimp farming systems are very diverse in their management, size and the people involved (Table 3). Shrimp farms can be classified in numerous ways, such as traditional and intensive or extensive, semi-intensive and intensive. These categories are characterized by increasing stocking rates, feed and water management inputs and yields [2, 4, 13, 14]. However, these categories are not consistently defined and are being continuously updated as technology improves [6]. New super-intensive farms now also exist [15], but extensive farms still contribute significantly to global farmed shrimp production [4]. Approximately 50–60% of all farms are extensive [6, 7, 16] (Figure 2) contributing to employment for many poor farmers especially in Asia [4]. In contrast, semi-intensive and intensive farms require technical and managerial expertise usually from outsiders. The survival rate and yearly production increases with intensity but so do the development and operating costs and with that the breakeven price of shrimp [14]. Shrimp pond sizes are also very variable (Table 3). The need for extensive farms to be situated in intertidal areas for water exchange and their large size are the reasons why they were responsible for significant mangrove habitat loss, especially in Asia [2]. Semi-intensive and intensive farms although usually smaller in size have also contributed to mangrove loss and degradation both through habitat clearance and other environmental impacts such as the addition of artificial feeds, chemical inputs and water requirements.

Loss of Mangroves

Mangrove forests are found in 121 countries [17]. They principally fringe the intertidal zone along sheltered coastal, estuarine and riverine areas in tropical and subtropical latitudes but can also occur in coastal lagoons and the supralittoral zone [18, 19]. The most extensive and diverse are found in the Indo-Pacific region [20]. The Sundarbans is the world's largest intact area of mangrove shared by Bangladesh and India [21, 22]. FAO [17] presents the most recent, reliable and complete estimates of world mangrove cover although even these lack some recent information and are only indicative. The figures also do not provide information on the rate of degradation or fragmentation, which also has impacts on the health and functioning of the ecosystem [18, 23, 24]. In 2000, it was estimated that there were 146 530 km^2 of mangroves in the world, with 40% in Asia and 23% in Africa (Table 4). The area of mangrove cover ranges from a few stands to thousands of kilometres between countries. The countries which have the most cover are Indonesia (29 300 km^2), Brazil (10 100 km^2), Nigeria (9970 km^2) and Australia (9550 km^2), accounting for 41% of all mangroves, with 60% of the total global mangrove cover in just ten countries [17].

The earliest records of mangrove cover dates back to 1918 for the Philippines [25], where it was estimated that there was 4000–5000 km^2. Current estimates of mangrove cover for the Philippines are 1097 km^2 [17], showing a 78% decline since records began, compared with 47% since 1980 figures (2065 km^2). The original global extent of mangroves is not known but conservative estimates suggest a 50% decrease in the global extent to present day figures, although, the most rapid losses have been in the last 50 years [26]. FAO [17] reported a global decrease in mangrove cover of 26%, 50 000 km^2, since 1980 estimates of 198 090 km^2. The extent of mangrove loss varies greatly depending on region and country. For example, South America has lost almost 50% of its mangroves and Singapore 81% since 1980 estimates [17]. The rate of mangrove loss also varies with time. There is a lower global rate of mangrove loss in the 1990s than the 1980s, 10% compared with 17% per decade, but in some regions and countries the rate has increased or remains the same. Brazil and Indonesia are still the top countries with the highest losses of mangrove. Conversely, Bangladesh has increased in mangroves due to afforestation on land formed by accretion [27, 28].

There are many causes for mangroves loss. Exploitation of mangroves for forestry uses, such as for timber, firewood, charcoal and woodchips by traditional or commercial users can cause considerable losses in mangrove

Table 3 Generalized classification of different farming systems for shrimp

Parameter	Traditional [14]	Extensive [6]	Semi-intensive [6]	Intensive [6]	Super-intensive [15]
Stocking density (no./m^2)	<1	<5	5–25	>25	115–130
Stocking characteristics	Wild post-larvae	Wild post-larvae some caught	Wild caught broodstock and wild or hatchery post-larvae	Broodstock wild caught or farm raised and hatchery post-larvae	Farm raised broodstock and hatchery post- larvae
Food	Natural food	Natural food (occasional supplementary feeds and/or low fertilization)	Natural food and/or artificial feeds/ fertilization	Artificial feeds and/or fertilization	Intensive artificial feeds but low protein
Water management (% exchange/ day)	Tidal	Tidal or pump 0.5%	Pumping 5–20%	Pumping 25–50%	Water recirculation and treatment
Aeration	None	None	Partial or continuous	Partial or continuous	Continuous
Labour inputs (workers/ha)	Family	<0.1	0.1–0.5	1–3	5
Production costs	Existing pond	Existing pond and operation costs 1–3USD/ kg	Existing pond, development and operation costs 2–6USD/kg	Development and operation costs high 4–8USD/kg	Development costs 800 USD/ km^2 operation costs also high/ km^2 but low/kg
Annual yield (tonnes/ha)	0.1–0.5	<1	1–5	>5	8–28
Pond area (ha)	1–20	1–100	<1–20	0.1–2	0.065–1.6
Elevation and land type	Intertidal, mangroves	Intertidal, mangroves	Intertidal and supratidal, mangroves	Supratidal, mangrove margins, agricultural land	6 m, pine savannah, lined ponds
Examples countries practiced	Philippines	Vietnam, India	Brazil, Australia	China, Thailand	Belize
Environmental impact	Low	Uses wide mangrove areas	Mangrove conversion, salinization, water pollution	Salinization, water pollution	Low apart from high energy use

cover if not sustainably managed [29–32]. However, the biggest threat is the high population and development pressures experienced in coastal wetland ecosystems across the world [33]. High population pressures and the underestimation of the total economic value of mangrove ecosystems have led to mangroves being converted to other uses such as agriculture, aquaculture, salt ponds, urban and industrial expansion, including infrastructure and tourist resorts [23, 29]. Off-site activities such as pollution from land or sea, such as industrial effluent, human waste and oil tankers can disrupt ecosystem processes and put further strain on coastal ecosystems [18, 30, 31]. Many of the problems and causes of mangrove loss stem from failures in policy, management and enforcement [18, 34].

The loss of mangroves by shrimp farming has caused considerable attention and controversy. Studies to quantify the global loss vary from 5% [2, 4], 10% [35] and 38% [30]. Overestimations of mangrove loss occur when areas other than mangroves are included and underestimations occur when disused ponds are not included. Given the unreliability of such data, particularly on mangrove status and quality, it is difficult to assign a global figure. Nevertheless, what is clear is that the rise in shrimp farming has affected some countries more than others, such as Ecuador, Philippines and Vietnam showing a closely related decline in mangrove cover with increasing shrimp production [2, 4, 14]. Furthermore, as well as causing wetland habitat loss there is consensus on a number of other environmental issues and socio-economic problems

Figure 2 Extensive shrimp farms with an integrated mangrove plantation in the Mekong Delta, Vietnam

posed by commercial shrimp farming in mangrove ecosystems.

Major Issues

Mangrove ecosystems are important coastal wetland ecosystems that perform many significant environmental and socio-economic functions [23]. Mangroves can provide a large supply of wood and non-wood forest products [31, 36], coastal protection against storm surges, reduction of shoreline and riverbank erosion and flood control [37, 38]. Mangroves provide a safe habitat and feeding area for birds, endangered mammals and a wide range of benthic and pelagic aquatic species [39–41]. They also act as a nursery ground for a variety of fish, shellfish and invertebrates many of which have commercial value [40, 42–45]. The organic materials produced by mangroves fuel the complex estuarine and nearshore food webs, making them an important ecological link between terrestrial and marine habitats such as peat swamps, salt marshes, seagrasses and coral reefs. The livelihoods of many local communities depend on the forestry and fishery products from mangrove ecosystems [46]. Mangrove degradation and conversion thus leads to loss of these important functions, especially when the number of farms exceeds the environmental carrying capacity [47, 48]. For example loss of coastal protection was shown to devastating effects during the 2004 tsunami in many coastal areas of Asia [49].

There is a wide range of other environmental issues and socio-economic problems related to the shrimp

Table 4 Global extent of mangrove area cover in km^2 by region and percentage change for the past two decades [17]

				% Change		
Region	1980	1990	2000	1980–1990	1990–2000	1980–2000
Asia	78 570	66 890	58 330	−14.9	−12.8	−25.8
Africa	36 590	34 700	33 510	−5.17	−3.43	−8.42
N&C* America	26 410	22 960	19 680	−13.1	−13.1	−25.5
South America	38 020	22 020	19 740	−42.1	−10.4	−48.1
Oceania	18 500	17 040	15 270	−7.89	−10.4	−17.5
World total	198 090	163 610	146 530	−17.4	−10.4	−26.0

*N&C=North and Central.

Table 5 Major issues and impacts of shrimp farming and better management guidelines [4]

Issue and impacts	Better management guidelines
Construction of ponds, embankments, canals and infrastructure can lead to loss of mangrove habitat, productivity, biodiversity and ecological functions such as coastal protection and lead to coastal erosion, saltwater intrusion and interference with hydrology. Potentially acid sulphate soils when excavated oxidize and can lead to excessively acid conditions which are harmful for shrimp and other species and can lead to pond abandonment.	Position new shrimp farms outside mangrove habitats. Minimize disturbance of acid-sulphate soils. Use pond liners. Canals and infrastructure located so do not affect hydrology. Farm design retains buffer zones between farms and other users and practices minimize erosion and salinization. Extensive farms intensify or diversify. Reuse or rehabilitate abandoned shrimp farms by establishing hydrology.
Dredging and deposition of sediment from pond bottoms and construction can lead to changes in hydrology and excessive sedimentation.	Allocate area for treatment of pond bottom solid waste by sun drying and oxidation e.g. use aerated settlement ponds to settle solids.
Fishmeal or wild fish fed to shrimp is 2–3 times as much as weight of shrimp produced leading to depletion of fish stocks. Feed is not efficiently utilized and effluent waters evacuated from ponds are loaded with organic matter and nutrients such as nitrogen and phosphorous due to leftover feed which can cause eutrophication.	Minimize feed loss through better feeding strategies. Use of formulated feeds with less fishmeal. Promote pond productivity to produce shrimp feed. Use filter feeders such as mussels and seaweeds to absorb nutrients in discharge channels. Create incentives for waste treatment and biofiltration. Establish standards for effluent treatment.
Fertilizers are used to stimulate plankton growth on which the shrimp feed. Lime is added to adjust acidity of water. Other chemicals such as formalin and chlorine are used to kill pathogens. Antibiotics and other medicines are added to water and feed as prophylactics. Some of these chemicals and medicines have toxic effects to non-target aquatic species and health issues to human consumers.	Ensure food safety and quality of shrimp products, while reducing the risks to ecosystems and human health from chemical use with legislation and enforcement for chemicals and drugs use. For example some chemicals and drugs have been banned and use of antibiotics banned for prophylactic use and must be administered as last resort under strict guidelines. Development and use of vaccines.
High volumes of clean water may be required to flush the system or reduce salinity. If freshwater is drawn from aquifers it can reduce supply of potable, agricultural and other industrial water. In some countries this has resulted in aquifers being drained, salinization of soil and groundwater and subsidence.	Minimize use of ground freshwater. Use appropriate wastewater treatments with low water exchange strategies such as closed or semi-closed systems. Develop water quality and quantity standards. Create incentives to reuse water.
Wild post-larvae and broodstock are often required to stock shrimp ponds and the capture of post-larvae kills a large by-catch of other species. Hatchery post-larvae may cause spread of diseases and escapes of introduced non-native species can cause genetic pollution and perhaps viability of wild populations.	Use of good quality hatchery produced post-larvae. Use of local species or domesticated stocks to enhance health and performance. Quarantine and acclimatize before release into pond. Take precautions to prevent escapes.
Restricted access to mangroves and reductions in mangrove resources used by local people can lead to the loss of livelihoods, food insecurity, marginalization and social conflicts.	Local people should participate in planning and implementation of shrimp farming. Farm operations should minimize impacts on resources. Tenure to land resources. Ensure health, safety, rights and welfare.

farming industry (Table 5), which have been extensively studied, documented and discussed [2, 4, 9, 13, 14, 32, 50–57]. The impacts depend on a wide range of interrelating factors such as the farming system management, size, location, environmental characteristics and quantity and quality of resources and are highly variable from site to site [4]. The major environmental issues include the pollution of waterways with pond effluents, chemicals and medicines, soil and groundwater salinization, the use of wild fish for feed and the capture of wild shrimp seed and their effects on aquatic biodiversity. The major socio-economic problems are compounded by the environmental issues, but with shrimp farms changing a free-access, multiple-use resource to a privatized, single-purpose resource, this can reduce employment opportunities and livelihoods [57]. Local poor communities rarely benefit from the profits of shrimp farming bringing social imbalance and marginalization. Food security has also been adversely affected because: shrimp are mainly for export; fisheries have declined due to mangrove conversion; shifting of agriculture such as rice fields to shrimp and increasing demand for fishmeal. These issues have led to social conflicts in some areas [9, 58].

Some intensive shrimp farming practices have also had negative impacts on the industry itself causing the sustainability of shrimp farming to be questioned. When large areas of mangroves are cleared and the ecological support functions of mangroves are lost or become severely reduced there is a decrease in wild shrimp broodstock and post-larvae [2, 47]. Introductions of non-native post-larvae are also thought to have contributed to disease outbreaks [59]. The excavation of ponds in

potentially acid sulphate mangrove soils has led to soil oxidation and excessively acid conditions which are harmful for shrimp as well as other animals and plants leading to the ponds having to be abandoned after a few years [60]. More explicit costing of the environmental services provided by mangrove ecosystems demonstrates that low intensity, but sustainable, harvesting has far greater long-term value to local stakeholders and the wider community than large shrimp aquaculture developments [61]. The rapid development of the shrimp industry, poor planning and management by shrimp farmers and governments has led to these issues and impacts occurring in numerous places around the world. For shrimp farming to be sustainable it needs to be conducted in ways that are environmentally and socially responsible.

Management Strategies

Global awareness about the need to reduce the impacts of shrimp farming and the importance of sustainable use of mangrove ecosystems has led to a number of related international, national and local technical, policy and legislative guidelines being published, addressing the shrimp industry and mangrove management. Interventions can occur before, during or after shrimp farming development [2]. Prior to introduction or further development of shrimp farming effective policy and planning interventions, such as legal, institutional and regulatory frameworks that require environmental impact assessments (EIA) and zoning of coastal land. Codes of Conduct, Codes of Practice, Best Aquaculture Practices (BAP) and many technical manuals promote voluntary better management practices during operation. Together with certification of better management practices such as the production process and introduction of certified fair trade, organic, eco-labels and shrimp traceability. After shrimp farming has stopped interventions are associated with changes in land use and rehabilitation efforts. Responses can be applied at different levels from international, regional and national levels to the private sector and local communities.

Policy and Planning

Policy, legal and institutional frameworks play an important role in coastal land use. At the international level, there are a number of frameworks and agreements to help governments manage coastal areas. These include protected area frameworks, such as the Ramsar Convention [62], and Man and the Biosphere Reserves [63] and international agreements for regulating pressures on marine resources such as the FAO Code of Conduct for Responsible Fisheries (CCRF) and specifically aquaculture through Article 9 [64]. Principles for a Code of Conduct for the Management and Sustainable Use of Mangrove Ecosystems is also being developed to address the environmental, social, economic and legal issues arising from the various sectoral uses of mangroves, including aquaculture [19]. In 2006, the Shrimp Farming and the Environment Consortium (consisting of the World Bank, the Network of Aquaculture Centres in the Asia-Pacific (NACA), the World Wide Fund (WWF) for Nature and FAO) adopted and published International Principles for Responsible shrimp farming [65]. There are also a number of regional and national guidelines for responsible aquaculture [34]. GAA an international industry-based organization has a set of Guiding Principles for Responsible Aquaculture and published Codes of Practice for Responsible Shrimp Farming [11]. Non-Government Organizations (NGOs) have also given statements and declarations concerning unsustainable aquaculture [66, 67]. All agree that the simplest and most effective method to reduce the impacts of shrimp farming on mangroves is to locate new farms behind the intertidal zone. Policies banning mangrove utilization for shrimp farms are now being actively promoted in several Southeast Asian countries [2, 4]. This also involves effective coastal zone planning, aquaculture zoned behind mangroves and in balance with natural habitat [34]. Other regulations include EIA, mitigation measures, farms licenses and rules for disease control and drug use. However, these regulations on their own or together do not ensure ecologically sustainable development. The ecosystem approach to aquaculture and mangrove management is currently being promoted as the way forward [19, 68–70].

Governance-related problems, inadequate policy, legal frameworks and development strategies are the main difficulties experienced in implementation of National Codes of Conduct based on the CCRF [68]. The lack of progress in implementation of the CCRF after 10 years is linked to weak institutional capacity, lack of resources, limited availability of relevant scientific, social and economic information and limited consultation with relevant stakeholders [68]. Coordination between different institutional sectors and levels, implementation and enforcement has to be effective or mangroves can continue to be converted [71]. Property rights, land tenure and participation of local communities in decision-making and management are also very important for success [18, 19, 68, 71, 72]. Partnerships, stewardship schemes and multilateral cooperation schemes where there is strong participation of local communities, a diversity of activities and administration at the local level result in successful policy and planning initiatives [2, 73] (Figure 3). Public awareness and the support of NGOs also play an important role.

Better Management Practices

Better management practices (Table 5) were identified from the extensive worldwide research and case studies

Figure 3 Successful community-based mangrove reforestation project in Kalibo, Aklan, Philippines. Recognized nationally with several awards and used as a model for mangrove reforestation projects and now promoted as a regional ecotourism site

carried out by the Shrimp Farming and the Environment Consortium from 1999 to 2002 [2, 4, 6, 15, 56, 59, 72, 74, 75]. Some 6–10 activities appear to account for most of the impacts of the global shrimp industry and in 66–75% of instances mitigation measures in the form of better management practices pay for themselves in 2–3 years [4]. Many of the better practices are linked but not all will be appropriate in all cases [4]. Specific practical manuals are being produced such as better management practices for *P. monodon* in tambaks in Aceh, Indonesia [76, 77]. To encourage adoption of better management practices governments should provide incentives. The shrimp aquaculture industry has taken proactive responses and introduced self-regulatory measures with technological improvements (in nutrition, selective breeding, disease control and intensive production systems) and the quantitative BAP programme for shrimp farm certification [11]. There should be constant improvement to better management practices to reduce impacts and increase efficiency. Integrated, mixed or mangrove-friendly aquaculture practices are potential alternatives that are particularly attractive to poor farmers and extensive farms [78–81].

Certification

Certification may be one way forward for ensuring environmental sustainability, social equity and food safety of aquaculture products. There are a growing number of

certification schemes such as certified fair trade, organic, eco-labels and shrimp traceability that can benefit both the local communities and the consumer but increasing competition between schemes may lead to confusion for buyers and consumers [82]. Aquaculture producers recognize that certification programs will help them in the increasingly competitive market and governments recognize that they can use certification schemes for permitting and licensing producers [83]. Raising willingness to pay by appealing to personal health issues through promoting organic products may be an effective policy to lever environmental impacts at production but consumers' willingness to pay for eco-labelled products is influential in their success [84].

The Aquaculture Certification Council (ACC) a new (2002) international non-profit organization applies GAA's BAP standards in a certification system for shrimp hatcheries, farms and processing facilities that combines onsite inspection and effluent sampling with mandatory requirements for product safety and traceability. This certification is primarily orientated towards seafood buyers and currently 38 farms from South America, Africa and Asia have been certified [85]. However, there has been opposition to the ACC by NGOs as being certification of industry by industry. NGOs have raised various issues concerning certification such as the need to involve participation of local communities, small-scale shrimp farmers and neighbouring communities, in the development of guidelines for aquaculture certification, consideration of costs of implementation of standards and certification for small-scale farmers, equivalence with existing standards, transparency and external verification. The international NGO WWF is producing a third-party certification criteria and standards for shrimp aquaculture certification [83]. In March 2007, FAO and NACA working in collaboration with relevant partners and stakeholders, initiated development of global guidelines on how aquaculture certification standards ought to be established and applied for governments, NGOs and private companies to ensure they are credible, trustworthy and fair [82]. However, some NGOs signed the Lampung Declaration against Industrial Shrimp Aquaculture in September 2007 declaring that the development of certification processes and misleading labels such as 'Ethical Shrimp' and 'Organic Shrimp' mask ecological damage, human rights violation and other real problems caused by the industry and urge consumers, retailers and governments to reject all the certification schemes developed thus far and those currently in development [86].

Mitigation and Restoration

If shrimp farming has to stop, for example, because of disease problems and the pond is left disused, interventions to mitigate impacts may involve rehabilitation [2]. This could be restoration of the original habitat, restoring the site to a sustainable shrimp pond operation or another productive use such as salt ponds, rice paddy fields or fruit trees, whichever is the most cost effective with the maximum benefits for the site [2, 60]. Restoration of the mangrove ecosystem is possible and has been successfully achieved in many countries provided the hydrology is restored [2, 76, 87, 88]. There are possible costs associated with collecting and planting mangrove seeds but the benefits of mangrove ecosystems (126–7833USD/ha/year) show that restoring shrimp ponds to mangrove ecosystems can be cost-effective [2]. However, success of restoration depends on awareness raising of stakeholders, provision of training and technical advice, economic and social incentives, penalties for non-compliance and land ownership [2, 76].

Conclusions

The increasing demand, supply and value of shrimp have led to unsustainable farming practices, environmental, social and economical impacts. Shrimp farming has not been the only reason for mangrove loss but because of its rapid development and concerns about its impacts it has raised awareness of the needs for sustainable mangrove management. There is consensus with local communities, NGOs, scientists, international organizations, governments and the shrimp industry that there is a need for the industry to change to be more environmentally and socio-economically aware and together with consumers and major buyers they are leading key sectors of the seafood industry to take responsibility for their performance. Numerous related international, national and local technical, policy and legislative guidelines have been published from international organizations, the private sector and NGOs addressing the shrimp industry and mangrove management. These include Codes of Conduct, Codes of Practice, better management practices and certification schemes, but many of them are voluntary and there can be confusion about which to follow. The simplest and most effective method to reduce impacts of shrimp farming on mangrove ecosystems is to zone farms behind the intertidal zone, but this policy is not effective without following an ecosystem approach, having good institutional capacity and coordination, effective enforcement, incentives, land tenure and participation of all stakeholders in management. Mangrove loss continues but is declining, reflecting that some countries have now banned their conversion. Better management guidelines have been identified to reduce impacts and increase efficiency and profits but may require incentives for adoption and should be constantly improved. Community-based management using partnerships, stewardships or multilateral cooperation schemes, together with integrated, mixed or mangrove-friendly aquaculture practices and mangrove rehabilitation should also be promoted. Local communities need to be involved in all decision-making

processes and their needs catered for before conflicts will cease to exist. Raising awareness of consumers especially in the United States, Japan and Europe, about where shrimp come from and how they are produced may also assist to drive promotion of ecologically sustainable and socially respectable farmed shrimp.

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