The role of crustacean fisheries and aquaculture in global food security: Past, present and future

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Minireview

The role of crustacean fisheries and aquaculture in global food security: Past, present and future

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ABSTRACT

The 1996 World Food Summit defined food security as "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".

This paper looks at the status of production from both shrimp capture fisheries and shrimp aquaculture, as well as trade, in order to understand the contribution of the crustacean sector to overall fish production and thus to global food security. This paper also examines some sustainability issues that will potentially affect the contribution of the crustacean sector (particularly shrimp) to food security. These include sustainable shrimp capture fisheries, sustainable shrimp trade and sustainable shrimp aquaculture.

The paper concludes that crustaceans are an important source of aquatic food protein. Production (as food and ornamental) and trade are extremely important for developing countries. It provides both economic development and empowerment in terms of contribution to GDP, consumption, employment, catch value and exports. The crustacean sector generates high value export products which enables producers to buy lower value products in the world market – thus a positive contribution to food security in both producing and exporting countries.

Contents

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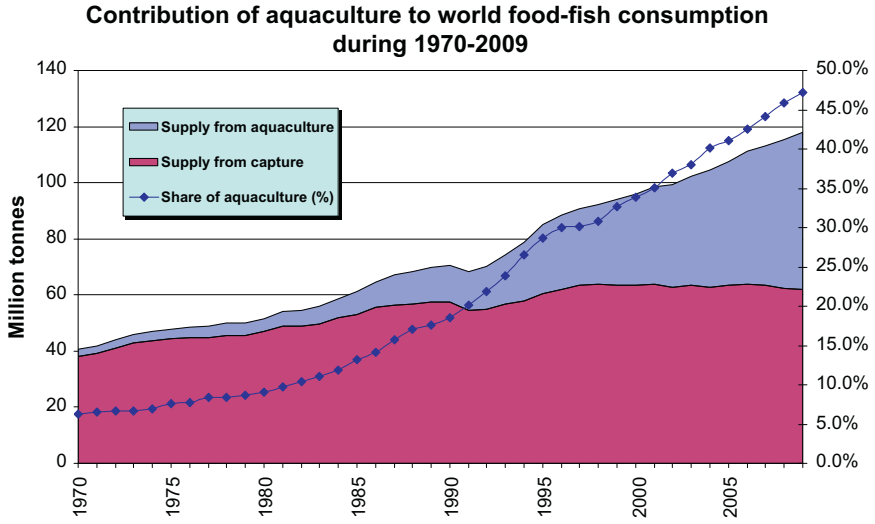

Fig. 1. Contribution of aquaculture to world food–fish consumption during 1970–2009.

1. Introduction

The World Food Summit (1996) defined food security as "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".

This paper looks at the status of production from both shrimp capture fisheries and shrimp aquaculture, as well as trade, in order to understand the contribution of the crustacean sector to global food security. This paper also examines important sustainability issues that will potentially affect the contribution of the crustacean sector (particularly shrimp) to food security.

2. State of world fish production and utilization

The most recent statistics (FAO, 2011) reported that capture fisheries and aquaculture supplied the world with about 144.6 million tons of fish in 2009. Of this, 117.8 million tons were used as human food, providing an estimated apparent per capita supply of about 17.2 kg (see Fig. 1). In 2009, crustaceans (63.7% of shrimps and prawns from both freshwater and saltwater) contributed approximately 11.2 million tons to the global fisheries and aquaculture production. Nearly 5.9 million tons came from marine capture fisheries and 5.3 million tons originated from aquaculture. Production from aquaculture is mostly destined for human consumption. In 2009, aquaculture accounted for 47.3% of the world's aquatic animal production for human consumption. In 2007, fish accounted for 15.7% of the global population's intake of animal protein and 6.1% of all protein consumed. The fish sector is a source of income and livelihood for millions of people worldwide. Employment in fisheries and aquaculture has grown substantially in the last three decades, with an average rate of increase of 3.6% per year since 1980 and currently accounts for about 44.9 million people worldwide (FAO, 2010).

During the period 2000–2008, the State of World Fisheries and Aquaculture (SOFIA) 2010 (FAO, 2010) reported that aquaculture production of all major species groups continued to increase. Crustacean production grew at an average annual rate of almost 15% during this period faster than the previous decade, compared to the finfish and molluscan sectors whose production grew more slowly than the period 1990–2000 (Fig. 2). The rapid increase in crustacean production largely reflects the dramatic increase in white leg shrimp (*Penaeus vannamei*) culture in China, Thailand and Indonesia.

According to FAO (2011), in terms of catch trends by valuable marine species group, shrimp catches have slightly decreased in recent years after a record high level of 3.3 million tons was reached in 2003 but remained at close to 3.2 million tons in 2009. The world's farmed crustaceans in 2009 came from brackish water (2.4 million tons, or 46%), freshwater (2.2 million tons or 40.9%) and marine water (0.7 million tons or 13.1%). Crustaceans farmed in freshwater include more than 0.5 million tons of the marine species white leg shrimp (*P. vannamei*) produced by China,

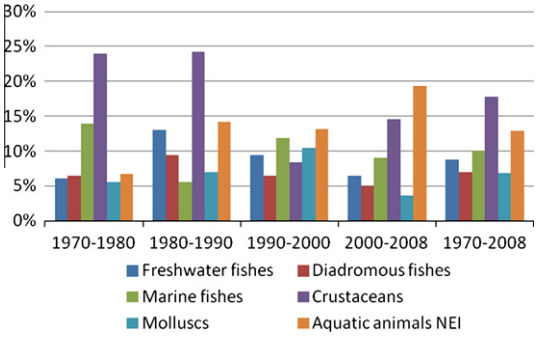

Fig. 2. Trends in world aquaculture production growth rate: average annual growth rate for major species groups: 1970–2008.

Table 1
Crustacean aquaculture production by species groups in 2008 and 2009 (FAO, 2011).

	2008		2009	
	Quantity (Ton)	Value (USD'000)	Quantity (Ton)	Value (USD'000)
Marine crustaceans				
Marine shrimp/prawns	3,403,195	14,374,250	3,495,972	14,647,939
Marine cabs	240,789	747,938	246,523	767,408
Other marine species	1206	12,007	1511	14,328
Sub-total	3,645,190	15,134,195	3,744,006	15,429,675
Freshwater crustaceans				
Freshwater crab	518,365	3,608,126	574,247	3,997,060
Crayfishes and other species	418,242	1,868,073	526,670	2,410,691
Freshwater shrimp/prawns	437,257	2,197,683	459,669	2,297,172
Sub-total	1,373,864	7,673,882	1,560,586	8,704,923

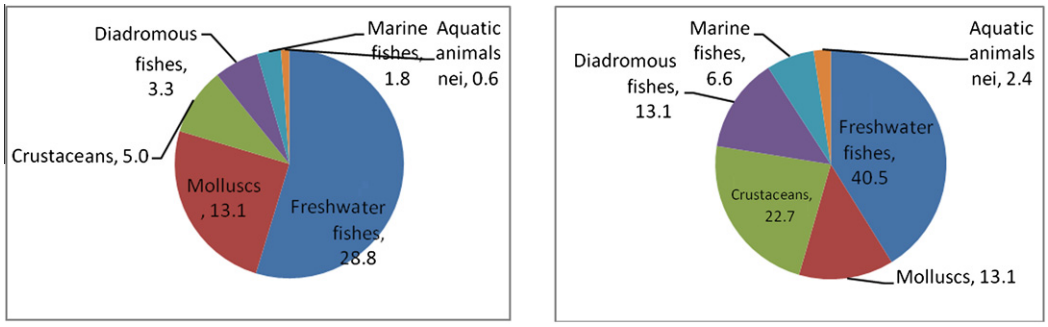

Fig. 3. World aquaculture production (left figure in quantity/volume terms; right figure in value terms): major species groups in 2008.

which was previously reported by FAO as production from brackish water.

Table 1 shows the 2008 and 2009 production by species groups showing the significant value of crustacean aquaculture production, in terms of quantity and value. Marine shrimp registered the highest in terms of quantity and value, followed by marine crabs, lobsters and freshwater crustaceans.

Farmed crustaceans form a significant component of current growth in the aquaculture sector and in the future, are expected to contribute a higher relative contribution to overall aquatic protein production. Crustaceans are also important to the approximate annual USD 300 million worth global trade in ornamental aquatic species. The industry for the production and consumption of aquatic crustaceans is truly globalized, with separation of net producer and net consumer nations requiring significant transboundary movements of live animals and their products.

According to SOFIA 2010 (FAO, 2010), in 2008, freshwater fishes continued to dominate (see Fig. 3) with a production of 28.8 million tons (54.7%) valued at USD 40.5 billion (41.2%), followed by molluscs (13.1 million tons), crustaceans (5 million tons, 23.1% valued at US$ 13.1 billion), diadromous fishes (3.3 million tons), marine fishes (1.8 million tons) and other aquatic animals (0.6 million tons).

3. Issues affecting the contribution of crustaceans to global food security

Gillett (2008), based on a study commissioned by FAO, reported examples of the important economic contribution of shrimp fisheries to selected countries in terms of the following indicators: (i) contribution to gross domestic product (GDP) (e.g. 1% of GDP for Madagascar, 0.25% of GDP for Norway, 0.2% of GDP for Trinidad and Tobago); (ii) consumption (e.g. 2.2 kg/person/yr for Australia, 1.9 kg for the USA, 1.7 kg for Norway, 0.66 kg for Mexico); (iii) employment (e.g. about 5% of all fishing employment in Australia, 1.2 million people in Nigeria involved in formal or informal jobs associated with shrimp fishing and post-harvest); (iv) catch value (e.g. USD 500 million in Indonesia, USD 425 million in the USA, USD 300 million in Mexico); and (v) exports. Shrimp represents the most valuable fishery export for countries such as Indonesia (USD 887 million), Mexico (USD 346 million), Madagascar (USD 68.2 million) and Nigeria (USD 49 million).

Aquaculture, on the other hand, currently contributes about 48% of aquatic animal food destined for human consumption and this is expected to surpass 50% by 2015. The additional supply, including crustaceans, required to meet the demand gap should come from aquaculture. Although the sector appears to be poised to meet this growing global demand for aquatic food, it is faced with several significant challenges which will determine its future sustainability. Demand for fish is going up in all regions, due to growing population and to health considerations of fish consumption. There, thus, exists a clear need, in the coming decades, for increased supply of fish protein, at affordable levels in relation to income and other proteins, in order to meet the health needs and general societal aspirations for global food security to the ever increasing global population. In order to fulfill these goals and aspirations, significant challenges need to be addressed. A number of important sustainability issues will affect the potential contribution of crustaceans, particularly shrimp, to global food security. The following three are deemed worthy of attention and consideration, namely: sustainable shrimp capture fisheries, sustainable shrimp trade and sustainable shrimp aquaculture.

3.1. Sustainable shrimp capture fisheries

The use of trawl gear is a major characteristic of most large-scale shrimp capture fisheries. While the number of shrimp trawlers in the world is not known, estimates in the late 1990s reported that there were about 140,000 trawlers of all types in the world's fisheries. Even as considerable interest exists in developing an alternative to shrimp trawling, no substantial progress has been made in replacing trawl gear and it remains as the main producer of important commercial shrimp species. In recent decades, most shrimp technology efforts have been towards improving trawl gear and techniques rather than developing new industrial shrimp fishing technologies (Gillett, 2008).

Bycatch, broadly defined as anything that a fisherman does not mean to catch, and which may include fish, turtles, pieces of coral, sponges, other animals and non-living material – is something that most commercial fisheries have to deal with (Eayrs, 2007). In shrimp fisheries, Eayrs (2007) reported that the bycatch from trawling consists of over several hundred teleost species and outweigh the shrimp catch by 20 to 1 or more. He further indicated that no other fishing method comes close to matching such discard and wastage of marine resources. Because valuable living resources are wasted, populations of endangered and rare species are threatened, stocks that are already heavily exploited are further impacted and ecosystem changes in the overall structure of trophic webs and habitats may result, bycatch is considered as one of the most pressing and controversial aspects of shrimp fisheries and much of management attention is focused on bycatch reduction (Harrington et al., 2005).

Shrimp resources are strongly exploited in all fishing areas. While the resource is considered fully exploited in the Atlantic Ocean, there are some signs of overexploitation in the Indian Ocean (mainly *Penaeus monodon*) and in the Eastern Central Pacific. Shrimp trawling can present a threat to food security since the capture and discarding of bycatch is a waste of an important aquatic food protein source. The high levels of unwanted and unreported bycatch and discards in many of the world's fisheries, including

the capture of ecologically important species and juveniles of economically valuable species, present significant concerns. Attention calling for actions on bycatch and discards has been raised during the 63rd session of the United Nations General Assembly in 2008 and the 28th session of the FAO Committee on Fisheries (COFI 28). Relevant organizations and stakeholders are urged to reduce or eliminate bycatch and discards, undertake research, and develop international guidelines (SOFIA, 2010).

3.2. Sustainable shrimp trade

Shrimp accounted for 15% of the total value of internationally traded fishery products in 2008. Shrimp remains the most valuable farmed species and the seafood species with the highest trade value (Asche and Bjorndal, 2011). The international market for shrimp is concentrated in the United States of America (USA), Japan and the European Union (EU); with the major exporting countries consisting of Thailand, China and Viet Nam.

A major player in the trade of shrimp products, the USA is the world's largest shrimp market. As such, the US government's import policies have a significant effect on major shrimp exporting countries throughout the world. It emerged as the largest importer in 1998 in volume and value when Japan, traditionally the largest import market for shrimp, experienced economic problems in the late 1990s which affected shrimp and other imported products in general (Gillett, 2008). Other factors at that time included the relative strength of the US economy, changes in the EU tariff structure which led to redirection of shrimp imports (e.g. Thailand, a major producer) to the US markets, better detection levels for banned substances such as chloramphenicol and nitrofurans which resulted again in the redirection of shrimp products from the EU to the USA.

Cultured shrimp plays an important role in the market. According to Ward et al. (2004) (cited in Gillett, 2008), a surge of shrimp imports into the USA over the last few years can be attributed to the following: (i) greater consistent quality of farm-raised shrimp than the wild product; (ii) less seasonality of supply thus better reliability than its wild counterpart; (iii) better control of species and sizes in farm-based system than in the wild; and (iv) better adaptation to consumer needs because of current trend towards vertical integration in the farming system.

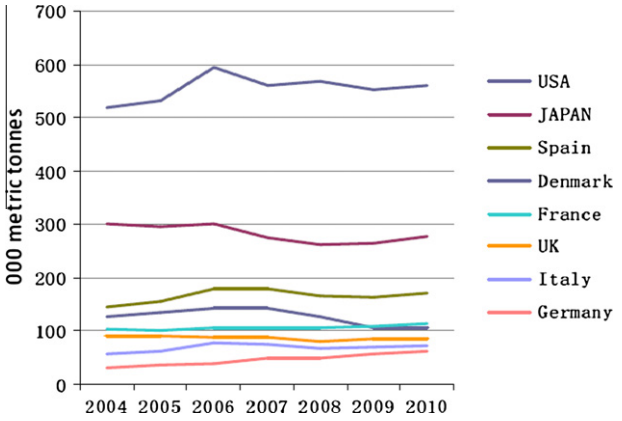

Fig. 4. Key shrimp importers from 2004 to 2010.

The general trend in shrimp imports for 2010 indicates a slight increase from all key shrimp importers, as shown in Fig. 4 below, except for Denmark, with the USA as the top importer.

Table 2 shows some trends in shrimp trade as compiled by FAO's Globefish (http://www.globefish.org/homepage.html), listing some factors affecting shrimp trade during the last 3 years. In 2009, shrimp trade was affected by a number of factors such as the global economic crises, cyclone, new regulation, consumer perception and disease. In 2010, the economic recovery and climate-related events and diseases are some of the factors which affected shrimp trade. In 2011, global economic crisis plays again a major role, together with the earthquake in Japan; on the other hand there is an increasing demand from developing countries.

3.3. Sustainable shrimp aquaculture

There are many issues concerning shrimp aquaculture sustainability. Major issues (past and emerging) include deforestation of mangroves to create land for the building of shrimp ponds, effluent discharge of waste water coming from shrimp farms use of antibiotics, use of fishmeal, general system intensification, food safety, transboundary aquatic animal diseases, certification schemes and trade (Josupeit, 2010; Chamberlain, 2010; Bondad-Reantaso et al., 2005, 2009; Bondad-Reantaso and Subasinghe, 2008). Biosecurity remains to be the biggest constraint to efficient production of shrimp under intensive aquaculture systems. Several serious diseases and substantial environmental challenges had affected aquaculture production growth. These two are closely interlinked as environmentally unsound practices increase the exposure to diseases.

Looking at cultured shrimp production trends, as well as drivers for major shifts in cultured shrimp species, will assist in better understanding the above-mentioned sustainability issues in shrimp aquaculture (see Fig. 5).

The culture of *P. vannamei* has attracted producers due to a number of competitive advantages in terms of the following parameters: faster growth rate, safe high stocking density, low salinity tolerance, cool temperature tolerance, protein requirements (less feed protein) and possibility of breeding and domestication and less disease compared to *P. monodon*.

The top *P. vannamei* producers for 2009 are shown in Table 3, including producers from Asia (China, Thailand, Indonesia and Vietnam) and Latin America (Ecuador, Mexico, Brazil, Colombia, Nicaragua and Peru). China and Thailand remained the top two producers from Asia and Ecuador and Mexico from Latin America since 2005. Vietnam is a special case. It used to be among the top five since 2005 and showed a great drop in production in 2008 and 2009. Indonesia and Brazil showed a decrease in production in 2009.

Table 2
Shrimp trade: trends and outlook. *Source*: Globefish commodity update at http://www.globefish.org/homepage.html.

2009	2010	2011
• Global economic crises • Cyclone Alia (Bangladesh, India) • H1N1 flu alarm (Japan) • Financial crisis • Disease (Indonesia) • New regulation (India) • Consumer perception	• Economic recovery • Climate change (Honduras, Viet Nam) • Disease (Viet Nam) • Poor pond management (Bangladesh) • Oil spill (Gulf of Mexico)	• Earthquake and tsunami in Japan • Economic crises in USA and Europe • Increasing demand from developing countries • Disease (Viet Nam, China)

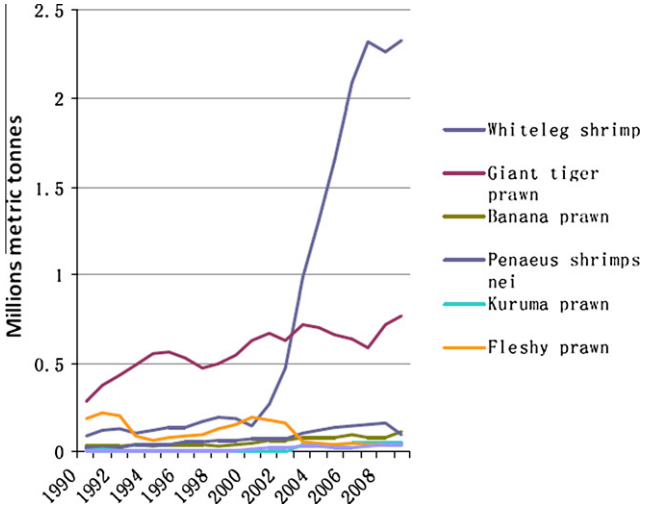

Fig. 5. Trends in cultured shrimp production: from 1990 to 2008.

Table 3
Aquaculture production (tons) of *Penaeus vannamei* in recent years (2005–2008); and top-10 producers in 2009. (FAO, 2011).

Producers	2005	2006	2007	2008	2009
China	702,484	887,838	1,065,644	1,062,765	1,118,142
Thailand	374,487	480,061	508,446	501,394	535,000
Ecuador	118,500	149,200	150,000	150,000	179,100
Indonesia	103,874	141,649	164,466	208,648	170,969
Mexico	90,008	112,495	111,787	130,201	125,778
Brazil	63,134	65,000	65,000	70,251	65,188
VietNam	100,000	150,000	153,000	38,600	36,000
Colombia	19,000	21,600	20,300	18,400	18,100
Nicaragua	9633	10,860	11,097	14,690	17,362
Peru	8324	9257	11,657	13,314	13,425
Others	60,811	62,155	55,737	57,083	48,470
World	1,650,255	2,090,115	2,317,134	2,265,346	2,327,534

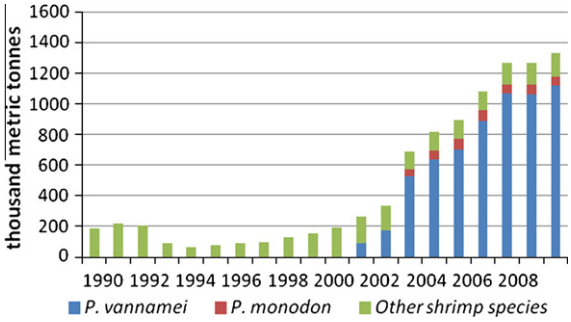

Fig. 6. Shrimp culture production in China from 1990 to 2008.

Although the shrimp disease situation in major shrimp producing countries are well known (see for example, Flegel, 2006a; Flegel et al., 2008; Lightner, 2003, 2011a,b), it might be useful to revisit some historical data as we try to understand what it might look like in the future. The following figures (Figs. 6–9) do not provide a direct correlation between aquaculture production and the impact of diseases as there are many other factors involved. However, the intention is to provide some perspectives on past and current production data and past and ongoing disease events through a few examples from some of the major cultured shrimp producing countries.

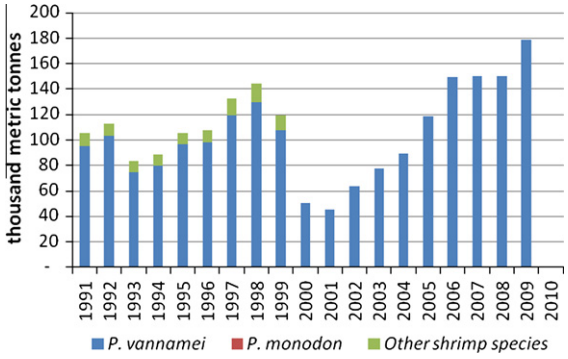

Fig. 7. Shrimp culture production in Ecuador from 1991 to 2009.

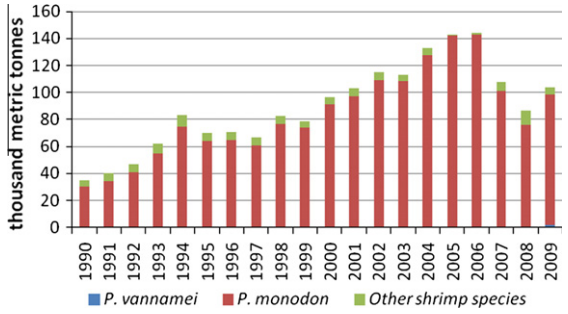

Fig. 8. Shrimp culture production in India from 1990 to 2008.

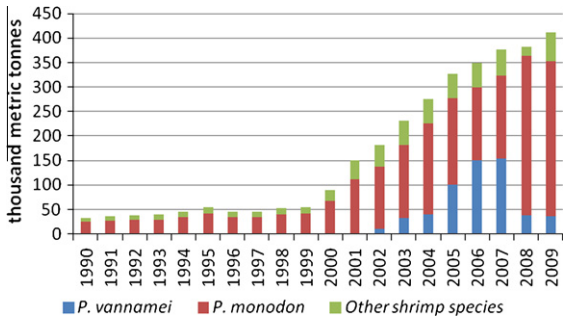

Fig. 9. Shrimp culture production in Viet Nam from 1990 to 2009.

3.3.1. China

In the case of China, Fig. 6 shows a decline in production from about 210,000 tons to 87,000 tons during the period between 1992 and 1993; severe shrimp diseases occurred in 1993 (Bondad-Reantaso et al., 2005).

3.3.2. Ecuador

In Ecuador, there was a drop in production from 1999 to 2001 (Fig. 7); there was a significant outbreak of white spot disease on *P. vannamei* during this period (Bondad-Reantaso et al., 2005).

3.3.3. India

In India, the occurrence of yellowhead disease and white spot disease during 1994–1995 resulted to production losses (Bondad-Reantaso et al., 2005). However, the drop in production between 2006 and 2008 was due to several factors including the following: decrease in farm gate price forced farmers to shift to *Pangasius* culture; detection of nitrofurans from shrimp exports resulted to return of consignments and forced farmers to shift to finfish farming. The Export Inspection Council of the Ministry of Commerce

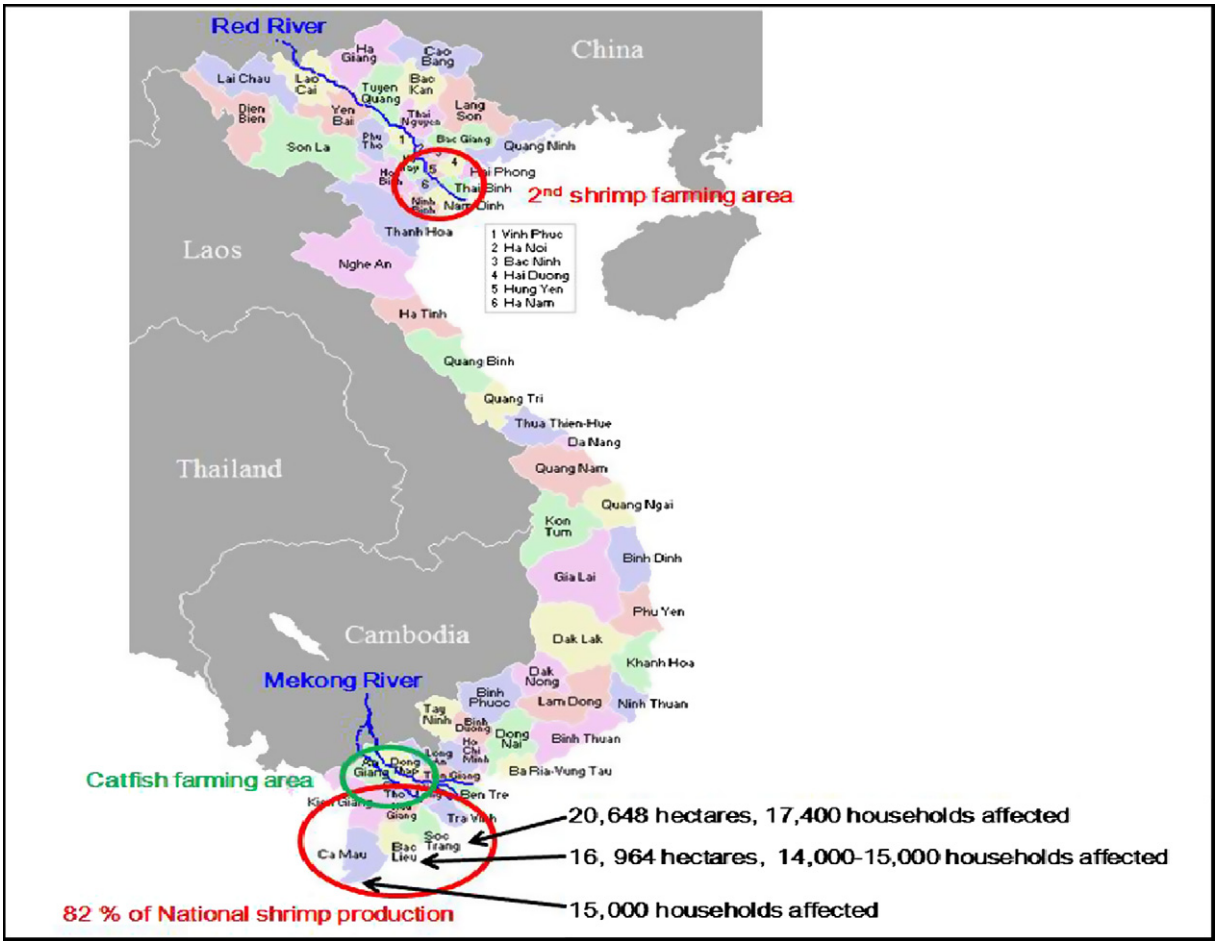

Fig. 10. Map of Viet Nam showing major shrimp farming areas in Mekong Delta and Red River, and reported affected area and households by the current outbreak (unknown disease) as of August 2011.

indicated that while disease has always been there since 2004, there appeared to be no major outbreak which caused a drop in production (I. Karunasagar, FAO, pers. comm.).

3.3.4. Viet Nam

Viet Nam is currently the no. 1 producer of tiger shrimp *P. monodon*, however the culture of *P. vannamei* is growing. As mentioned earlier, there is no information why there was a significant drop in production in 2008–2009 (Fig. 9). What is currently known, though, is that there is an ongoing unknown disease affecting shrimp in the Mekong Delta (since 2010, see Fig. 10), the main source (80%) of whiteleg shrimp production in the country. This unknown disease affects both *P. monodon* and *P. vannamei* and we will look forward to see whether the data to be reported in the future will reflect the impact of this disease outbreak in production.

3.3.5. Brazil

There was a decrease in production from 2003 to 2005 (Fig. 11). During this period, the country was suffering from infectious myonecrosis virus (IMNV) outbreaks in *P. vannamei* in 2002 (Lightner et al., 2004; Poulos et al., 2006). Reported losses during the first outbreak in Brazil was USD 20 M. IMNV causes significant losses (100% prevalence; 40–70% mortalities) in farmed populations in marine and low salinity brackish water.

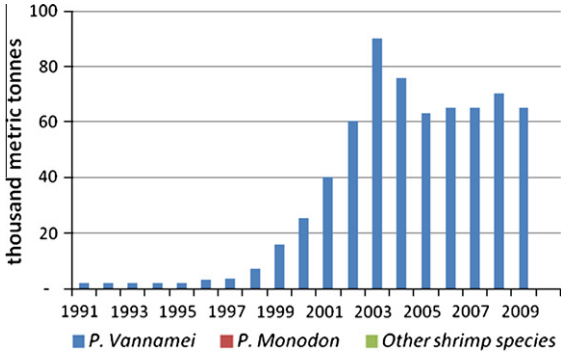

Fig. 11. Shrimp culture production in Brazil from 1991 to 2009.

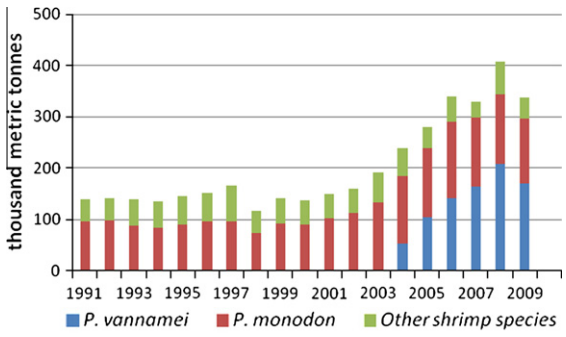

Fig. 12. Shrimp culture production in Indonesia from 1991 to 2009.

Fig. 13. Map of Indonesia showing the occurrence and spread of Infectious Myonecrosis Virus (IMNV) between 2006 and 2009.

3.3.6. Indonesia

In Indonesia, IMNV has been reported during the period 2006–2008 (Senapin et al., 2007; Saengchan et al., 2007) but looking at the production figure (Fig. 12), there does not seem to be an impact on production. The disease was reported to be spreading to several provinces in 2009, and here we can see a drop in production figures reported by the country. Since the disease has been reported to be spreading to several new provinces in 2010, it will be interesting to see whether this will affect the production data reported for that year.

The disease spread from one affected area (Situbondo District, East Java) during the period 2006–2008 then to neighboring islands in the east, west and north (West Kalimantan) since 2009. In 2010, East Java (Situbondo), Lampung, Central Java, West Kalimantan and West Nusa Tenggara were affected (E. Leano, NACA, pers. comm.) (see Fig. 13).

4. Outlook

Based on the recent OECD/FAO Agricultural Outlook for 2011–2020 (the 17th edition has for the first time included fisheries), growth of the fisheries sector will be based on aquaculture. The sector is projected to increase its total production by 1.3% annually to 2020, slower than over the previous decade due to a slower rate of growth of aquaculture (2.8% against 5.6% for 2001–2010) and a reduced or stagnant fish capture sector (OECD/FAO, 2010).

Many aquaculture systems, including those for shrimp, rely on unaccounted environmental goods and services. There is increased competition for natural resources. There are many uncertainties including, for example, the impact of climate change, future fisheries supplies for competition and feed, limits of scale of economics integration and the development and acceptability of new bio-engineering technologies. There are policy issues about the priority given to conserving the environment versus the exploitation of natural resources for food production. It is imperative that these issues and challenges are carefully addressed and the sector's sustainability is maintained or improved in order for the increasing prices of food be kept minimal so that all societies can afford to access aquatic food and the producers, processors and service providers will continue to make a living.

Although there was a notion that shrimp aquaculture has outcompeted other users which came under scrutiny due to overexploitation and destruction of mangrove resources, as well as other environmental impacts and serious disease problems, the sector now recognizes the wider ecosystem value of these environments and suitable protection is given in most regions. However, much remains to be done with respect to rebuilding lost area.

While fishmeal and fish oil are not essential for herbivorous and omnivorous species on nutritional grounds, much of the crustacean farming require a higher quality diet, usually containing fish meal and often fish oil. Although fish meal has also traditionally been used in intensive livestock rearing, shrimp aquaculture is currently taking a growing share of these resources (25% of fishmeal production in 2008) as substitutes are more easily found for livestock and poultry. If this trend continues, shrimp aquaculture will consume significant volumes of fishmeal and fish oil, thus, finding strategies for reducing reliance on these resources will have to be a priority.

Biosecurity and disease will continue to be the biggest constraint to efficient production of shrimp under intensive aquaculture systems. Recent advancements in shrimp health management are commendable and effective. However, new diseases will emerge, and previously rare diseases may become much more prevalent, so continued vigilance and solution development is required. Some biotechnologies such as vaccines do not apply to shrimp thus reducing risk of diseases in shrimp aquaculture will largely depend on the application of better husbandry and biosecurity management practices at farm level and the use of quality, high health, specific pathogen free (SPF) seed supported by strict biosecurity.

Importation of exotic crustaceans of any kind for aquaculture should go through the recommended risk analysis and quarantine procedures, combined with tests for unknown viruses that might be a danger to local species (Flegel, 2006b). Risk analysis is fundamental to assessing emerging threat from new, exotic and expanding species (Arthur et al., 2010; Bondad-Reantaso et al., 2009)). Such biosecure practices should also be applied even to exotic domesticated stocks that are SPF for a list of known pathogens. In order to prevent the continual risk of importing unknown pathogens associated with continuous importation of exotic stocks, investing in the development of local breeding centers with

biosecure facilities might provide some solution to address the issue of constant supply of broodstock and post-larvae needed to support sustainable production (Hine et al., in preparation).

Another pertinent issue concerns small-scale shrimp producers. The shrimp aquaculture sector has been dominated by small-scale farmers practicing extensive aquaculture. However, perhaps as a response to price uncertainties in the market to reduce unit cost of production, there is a growing trend towards industrialization and consolidation of shrimp aquaculture. It is important that measures are taken and that conducive policies are developed so that this trend will not push small-scale producers out of business, marginalizing the social responsibility of the sector.

5. Conclusions

Crustaceans are not only an important source of aquatic food protein, but also an important revenue earner for people engaged in the value chain. Production (as food and ornamental) and trade are extremely important for developing countries. It provides economic development and empowerment and significant contribution to food security. The crustacean sector generates high value exports which enable producers to buy lower value products in the world market – thus a positive contribution to food security in producing and exporting countries. Shrimp, in particular, is now the most important internationally traded fishery commodity in terms of value. In many tropical developing countries, it is the most valuable fishery export; the employment aspect is also significant. The economic importance of shrimp, however, needs to be reconciled with considerable concern about the environmental impacts of shrimp fisheries.

The aquaculture sector, in general, has grown to become a globally robust and vital industry compared to the other food producing sectors. The shrimp industry in particular is driven by the private sector. Governance and policy are becoming essential pillars to support sustainability of the sector – good governance that equitably provides an enabling environment to both the private sector entrepreneurs and the small-scale producers that are involved in this industry.

While the economic slump during the last few years maybe temporary in nature, there are indications from the OECD/FAO outlook that the prospects for fisheries and aquaculture are good. However, sustainability issues (i.e. shrimp fisheries, shrimp trade and shrimp aquaculture) discussed above need to be carefully addressed and practical solutions implemented.

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