The introduction of *Penaeus vannamei* and *P. stylirostris* into the Asia-Pacific Region[1]

Simon Funge-Smith[2] & Matthew Briggs[3]

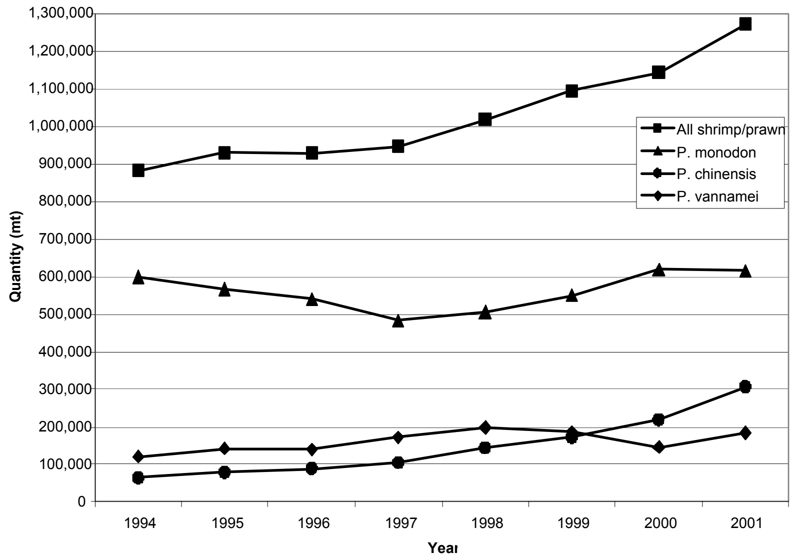
FAO Regional Office for Asia and the Pacific, Bangkok, Thailand

1. Background

In 2000, global aquaculture production reached 45.71 million metric tonnes (mmt) with a value of US$ 56.47 thousand million. This represented an increase in production of 6.3% by weight and 4.8% by value over the previous year. Although crustaceans represented only 3.6% of total production by weight, they comprised 16.6% of total global aquaculture by value in 2000. Despite being affected by serious disease outbreaks in both Latin America and Asia, the annual percent rate of growth (APR) of the shrimp sector grew by 6.8% by weight between 1999 and 2000. These growth rates are still high relative to other food production sectors , however in terms of growth, shrimp production has decreased to more modest levels over the last decade (averaging 5%) relative to the double-digit growth rates which were observed during the 1970's (23%) and 1980's (25%).

Marine shrimp continued to dominate crustacean aquaculture, with three major species accounting for over 86% of total shrimp aquaculture production in 2000 (the giant tiger prawn, *Penaeus monodon;* the fleshy prawn, *P. chinensis;* and the whiteleg shrimp, *P. vannamei*) (Figure 1). Whilst the giant tiger prawn only ranked 20th by weight in terms of global aquaculture production by weight in 2000, it ranked first by value at US$ 4.047 billion.

Figure 1
World production of cultured shrimp species (199
(Source: FAO website)



1This report is a summary or a more comprehensive review which is currently under preparation, please contact simon.fungesmith@fao.org for further information.
2 FAO Regional Office Asia and the Pacific, 39 Pra Athit Mansion, Bangkok 10200, Thailand
3 Consultant

2. Natural Range of P. Vannamei and P. stylirostris

Penaeus vannamei and *P. stylirostris* both originate on the Western Pacific coast of Latin America from Peru in the South to Mexico in the North. *P. vannamei* is native to the Pacific coast of Mexico, Central and South America as far south as Peru, in areas where water temperatures are normally >20^{o}C throughout the year (Wyban and Sweeney, 1991, Rosenberry, 2002). It is not currently known whether there is one population throughout the year or if isolated populations exist, although there do appear to be differences between stocks from various areas under culture conditions.

P. stylirostris is native to the Pacific coast of Central and South America from Mexico to Peru, occupying the same range as *P. vannamei*, but with higher abundance, except for in Nicaragua at the peak of the range of *P. vannamei* (Rosenberry, 2002). It has recently been demonstrated that there are at least 6 morphologically and genetically distinct populations of *P. stylirostris* in the Gulf of California, Mexico alone (Lightner et al., 2002), raising the probability that there will be variations in their suitability for aquaculture.

The culture industry for *P. stylirostris* in Latin America is largely confined to Mexico, but *P. vannamei* has become the primary cultured species in Latin America from the USA to Brazil over the past 20-25 years. Total production of this species in the Americas probably amounted to some 200,000 mt, worth $1.2 billion in 2002.

P. vannamei was introduced into Asia experimentally from 1978-79, but commercially only since 1996 into Mainland China and Taiwan province of China, followed by most of the other coastal Asian countries in 2000-01. Experimental introductions of SPF "supershrimp" *P. stylirostris* have been made into various Asian countries since 2000, but the only country to develop an industry to date has been Brunei.

3. Worldwide movements and introductions

The use of exotic animal species to increase food production and income has a long history and has been an established practice since the middle of the 19th Century. Controversy over the use of exotic species arises from the many highly publicised and spectacular successes and failures.

FAO statistics show that aquaculture development has been the primary reason cited for most introductions, accounting for 40% of all cases, and that the number of introductions (65% intentional) has increased exponentially since 1940. Most of these introductions are of fish, with only 6% or 191 records being of crustaceans. Such movements have been facilitated by recent advances in transport, which have made large-scale movements of many species increasingly easy. They are also directly related to the rapid global development of the aquaculture industry and the demand for new species to culture (FAO database of introduced aquatic species (DIAS), Fegan et al., 2001).

With regard to Penaeid shrimp, the first experimental movements began in the early 1970s, when French researchers in Tahiti developed techniques for intensive breeding and rearing of various exotic Penaeid species including *P. japonicus, P. monodon* and later *P. vannamei* and *P. stylirostris*. Later, in the late 1970s and 1980s, *P. vannamei* and *P. stylirostris* were translocated from their natural range on the Pacific coast of Latin America from Mexico to Peru. From here, they were introduced to the North-Western Pacific coast of the Americas in the USA and Hawaii, and to the Eastern Atlantic coast from Carolina and Texas in the North through Mexico, Belize, Nicaragua, Colombia, Venezuela and on to Brazil in the South. Most of these countries now have culture industries for these species. *P. monodon* and *P. japonicus* were also experimentally introduced in the 1980s and 1990s from Asia to various Latin American countries including the USA, including Hawaii (where SPF populations have been established), and Ecuador and Brazil, where introductions were not successful.

Table 1: Importation of *P. vannamei* and *P. stylirostris* in Asian countries.

Country	First Introduction of *P. vannamei*	Original source	Original Cultured Species	Reason for importing *P. vannamei*	First Introduction of *P. stylirostris*	Source of Brood/PL Imports	Current Ban on Imports	Current Viral Diseases
China	1988	Tx	C,M,J,P,Me	Diversification, performance	1999	Tx, Ti, Hi	No	WSSV,YHV,TSV,SMV,HPV,IHHNV,BP,MBV,BMNV,HB,LOPV,REO-III
Taiwan province of China	1995	Hi	M,J,Ma	Problems w. *P. monodon*	2000	Hi, Ch	No	WSSV, YHV, IHHNV, MBV,TSV
Thailand	1998	Ti	M,Me,J	Problems w. *P. monodon*	Yes	Hi, Mx, Ch, Ti	September, 2002	WSSV, MBV, BMNV, HPV, YHV, IHHNV, LOVV, TSV, MOV
Vietnam	2000	Ch	M	Prob. w. *P. monodon,* cold tolerance	No	Ti, Ch, Hi	Except for 9 licensees	WSSV, YHV
Philippines	1997	Ti	M,I,Me	Problems w. *P. monodon*	No	P, Ti	1993, 2001	WSSV, YHV
Indonesia	2001	Hi	M, Me	Problems w. *P. monodon*	2000	Ti, Hi	Restricted to license holders	WSSV,YHV,MBV,TSV, IHHNV
Malaysia	2001	Ti	M,S	Problems w. *P. monodon*	No	Ti, Th	June, 2003	WSSV, MBV, BMNV, HPV, YHV, IHHNV
India	2001	Ti	M,I,Ma	Problems w. *P. monodon*	No	Ti, Hi	Except for a few trials	WSSV, MBV, HPV,YHV
Sri Lanka	None	N/A	M	N/A	No	N/A	Guidelines in force	WSSV, YHV, MBV
Pacific Islands	1972	Mx, P	M,Me,J	Experiments, cold tolerance	1972	Mx, P, Hi	Fiji has Regulations	None

Notes:
Cultured species: C = *P. chinensis*, M = *P. monodon*, Me = *P. merguiensis*, I = *P. indicus*, S = *P. stylirostris*, J = *P. japonicus,* P = *P. penicillatus*, Ma = *Macrobrachium rosenbergii*
Source/Broodstock Imports: Hi =Hawaii, Ti = Taiwan province of China, Ch = Mainland China, Mx = Mexico, Th = Thailand, Tx = Texas, P = Panama

More recently, experimental introductions of *P. vannamei* to Asia began in 1978/79 to the Philippines (FAO correspondent) and in 1988 to Mainland China (FAO correspondent). Of these first trials, only Mainland China maintained production and started an industry. However, beginning in 1996, *P. vannamei* was introduced into Asia on a commercial scale. This started in Mainland China and Taiwan province of China and quickly spread to the Philippines, Indonesia, Vietnam, Thailand, Malaysia and India. A summary of the introduction of *P. vannamei* and *P. stylirostris* to Asia is presented in Table 1.

P. vannamei has been introduced and farmed in Asia since the mid 1990's, with production in Mainland China being particularly significant. There have been several reasons for the introduction and subsequent movement; apparent availability of specific pathogen free (SPF) stocks; perceived differences in susceptibility to WSSV from *P. monodon*; shortage of *P. vannamei* in the international market (mainly USA) caused by reduced production in Latin America, and the relative ease with which animals could be cultured and bred in captivity. In some countries, *P. vannamei* culture has been promoted by some private sector suppliers as being tolerant or resistant to WSSV, leading to introductions based on a mistaken belief that they are safe.

China has a large and flourishing industry for *P. vannamei*, with Mainland China producing >270,000 mt in 2002 and an estimated 300,000 mt (71% of total shrimp production) in 2003, which is higher than the current production of the whole of Latin America. Other Asian countries with developing industries for this species include Thailand (120,000 mt estimated production for 2003), VietNam and Indonesia (30,000 mt estimated for 2003 each), with Taiwan province of China, the Philippines, Malaysia and India also producing thousands of tonnes each.

Total production of *P. vannamei* in Asia was approximately 316,000 mt in 2002, and it has been estimated that this will increase to nearly 500,000 mt in 2003, which would be worth some $4 billion on the export market. However, not all the product is exported outside of the region and a large local demand exists in some Asian countries.

It is now evident that *P. vannamei* is farmed and established in several countries in East, Southeast and South Asia and is playing a more significant role in shrimp aquaculture production. On the other hand, it is also evident that viruses previously confined to Latin America, such as TSV are taking a toll within *P. vannamei* shrimp aquaculture in many countries in Asia and there have also been reports of "runt deformity syndrome" (RDS) caused by IHHNV, which is endemic in *P. monodon* in the region.

The overall performance of *P. vannamei* as a candidate species within shrimp aquaculture sector is still unclear. The knowledge and understanding of the social, economic, and environmental impacts of introduction of this species into Asia is far from adequate. It is uncertain how this species will behave and perform in the region, as a newly introduced species, and what impacts it will bring to the regional economy, environmental sustainability, rural livelihoods and regional biodiversity. Therefore, it is recognized that a review/study towards assessing the introduction and impacts of *P. vannamei* in the Asia-Pacific region is timely.

Stocks of IHHN-resistant *P. stylirostris* based on the Tahiti strain were also introduced into the region in recent years. Although these stocks did not become as widely distributed as *P. vannamei*, some stocks of *P. stylirostris* remain and there may be some interest in this species should RDS become a limiting factor.

4. Advantages and disadvantages of *P. vannamei* and *P. stylirostris*

There are many reasons for the introduction of *P. vannamei* and *P. stylirostris* outside of their natural range. Despite the presence of various international, regional and country-specific regulations, the private sector (and/or government) often initiate introductions due to problems with the culture of their indigenous species and the perceived (rightly or wrongly) production benefits of the exotic species. There may also exist marketing advantages, and a desire to expand, intensify and/or diversify aquaculture systems. Additionally, the improved transportation efficiency available recently has removed some old limitations and encouraged international trade in exotic species. The advantages and disadvantages of *P. vannamei* and *P. stylirostris* as compared to native species, specifically *P. monodon* are shown in Table 2.

The main reason behind the importation of *P. vannamei* to Asia has been the poor performance, slow growth rate and disease susceptibility of the major indigenous cultured shrimp species, *P. chinensis* in China and *P. monodon* virtually everywhere else. Cultured shrimp production in Asia has been characterised by a series of outbreaks of disease caused by viral pathogens which have caused significant losses to the culture industries of most Asian countries over the past decade. These disease have not been confined to single countries but have spread throughout shrimp culture regions apparently as a result of transfers of infected stock. It was not until the late 1990s, spurred by the production of the imported *P. vannamei*, that Asian (and therefore world) production levels have begun to increase again.

Despite the problems with disease transfer, *P. vannamei* (and *P. stylirostris*) does offer numerous advantages over *P. monodon* for the Asian shrimp farmer. These are largely associated with the ability to close the life cycle and produce broodstock within the culture ponds. This relieves the necessity of returning to the wild for stocks of broodstock or PL and permits domestication and genetic selection for favourable traits such as growth rate, disease resistance and rapid maturation. Through these means, domesticated stocks of SPF and SPR shrimp have been developed and are currently commercially available from the USA.

Other specific advantages include, rapid growth rate, tolerance of high stocking density, tolerance of low salinities and temperatures, lower protein requirements (and therefore production costs), certain disease resistance (related to SPR stocks), and high survival during larval rearing, and some marketing advantages. However, there are also disadvantages, including their acting as a carrier of various viral pathogens new to Asia, a lack of knowledge of culture techniques (particularly for broodstock development) in Asia, smaller final size and hence lower market price than *P. monodon*, need for high technology for intensive ponds, competition with Latin America for markets, and a lack of support for farmers due to their often illegal status.

Since it is clear that *P. vannamei* culture is already established and growing fast in the Asian region (Table 3), it is important that informed decisions regarding these advantages and disadvantages and appropriate action needs to be taken. This would ideally develop with a close dialogue between government and private sector as well as other concerned organisations.

Table 2: Summary of advantages and disadvantages of the culture of *P. vannamei* and *P. stylirostris* over *P. monodon* in Asia

Characteristic	Advantages	Disadvantages
Growth Rate	*P. vannamei* and *P. stylirostris* can grow as fast as *P. monodon* up to 20g and typically grows faster (1-1.5g/wk) than *P. monodon* (1g/wk) currently in Asia; Size range on harvest generally smaller	Growth rate of *P. vannamei* slows after reaching 20g, making production of large-sized shrimp slower
Stocking Density	*P. vannamei* is easier to culture in very high densities (typically 60-150/m^2, but up to 400/m^2) than *P. monodon* and *P. stylirostris* which can be aggressive	Very high stocking densities require high control over pond/tank management practices and are high-risk strategies
Salinity Tolerance	*P. vannamei* are tolerant of a wide range of salinities (0.5-45ppt) and more amenable to inland culture sites than *P. monodon* or *P. stylirostris*	None
Temperature Tolerance	*P. vannamei* and particularly *P. stylirostris* are very tolerant of low temperatures (down to 15^{o}C) enabling them to be cultured in the cold season	None
Protein Requirements	*P. vannamei* require lower protein feed (20-35%) than *P. monodon* or *P. stylirostris* (38-40%), resulting in a reduction in operational costs and amenability for closed, heterotrophic systems; FCRs are lower at 1.2 compared to 1.6	None
Disease Resistance	Although *P. vannamei* is susceptible to WSSV, Asia is not currently experiencing problems from this virus; *P. stylirostris* is highly resistant to TSV; Both species have been selected for resistance to various diseases; Survival rates with *P. vannamei* are thus currently higher than with *P. monodon* in Asia and production is more predictable	*P. vannamei* is highly susceptible to and a carrier of TSV, WSSV, YHV, IHHNV and LOVV; *P. monodon* is refractory to TSV and IHHNV; There is currently no ability to select *P. monodon* for disease resistance
Ease of Breeding and Domestication	Availability of pond-reared broodstock; Ability to conduct domestication and genetic selection work; SPF and SPR lines already available; Elimination of problems associated with wild broodstock and/or PL collection; source of cheap broodstock from ponds; small sized broodstock mean faster generation times	SPF animals sometimes have high mortality in disease-laden environments; Broodstock rearing and spawning more technical and complicated than use of wild *P. monodon* spawners
Larval Rearing	Higher survival rates in hatchery of 50-60% for *P. vannamei* and *P. stylirostris* compared to *P. monodon* (20-30%)	None
Post-Harvest Characteristics	If treated with ice, *P. vannamei* are resistant to melanosis	Handling, transportation and processing of *P. monodon* easier
Marketing	White shrimp generally preferred in US market over tigers due to taste; Strong local demand for white shrimp in Asia; The meat yield is higher for *P. vannamei* (66-68%) than for *P. monodon* (62%)	*P. monodon* and *P. stylirostris* can grow to a larger size, commanding a higher price than *P. vannamei*; High competition on international markets for *P. vannamei* as production is world-wide
Origin	None	*P. vannamei* and *P. stylirostris* are exotic to Asia and their importation may cause problems with import of new viruses and contamination of local shrimp stocks
Government Support	None	No support from most countries since they remain undecided or ban imports and farming of *P. vannamei*; Supply of broodstock and seed problematic in face of bans, leading to smuggling of sub-optimal stocks and disease introduction

Table 3: Estimated Production of all shrimp and *P. vannamei* in Asian countries.

Country	Total Shrimp Production (mt/yr) 2002	Total Shrimp Production (mt/yr) 2003	*P. vannamei* Production (mt/yr) 2002	*P. vannamei* Production (mt/yr) 2003	*P. vannamei* Production (% of total) 2002	*P. vannamei* Production (% of total) 2003
China	415,000	420,000	272,980	300,000	66	71
Taiwan Province of China	18,378	19,000	7,667	8,000	42	42
Thailand	260,000	300,000	10,000	120,000	4	40
Vietnam	180,000	205,000	10,000	30,000	6	15
Philippines	36,000	38,000	3,425	5,000	10	13
Indonesia	100,000	130,000	10,000	30,000	10	23
Malaysia	23,200	27,000	1,200	3,600	5	13
India	145,000	150,000	350	1,000	0	1
Sri Lanka	3,368	3,400	0	0	0	0
Pacific Islands	2,200	2,200	0	0	0	0
Total	**1,183,146**	**1,294,600**	**315,622**	**497,600**	**27**	**38**

Note : all date for 2003 is estimated

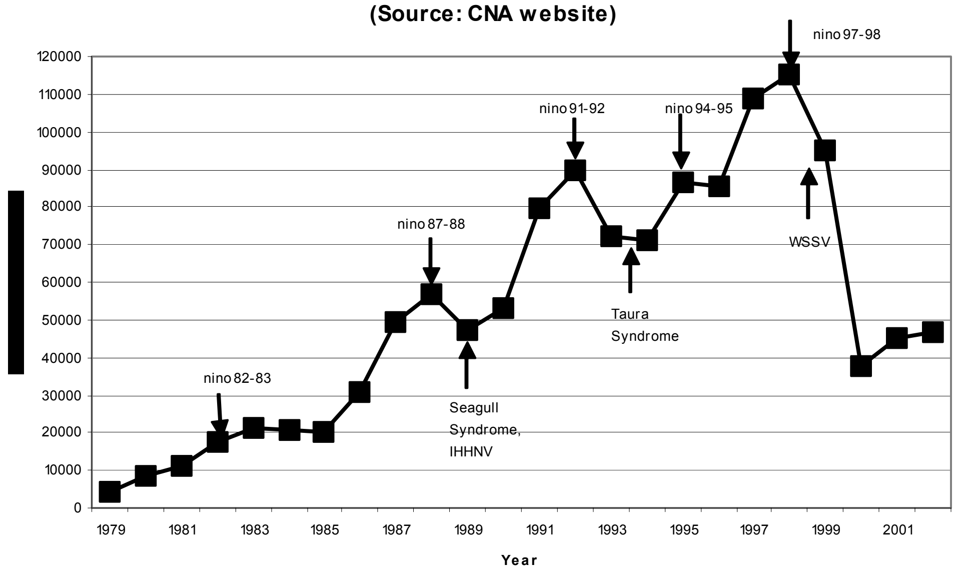
5. Threats and risks of introducing exotic shrimp species

Unregulated trans-boundary movement of aquatic animals can lead to substantial economic and environmental impacts through the transfer diseases and pathogens. Trans-boundary pathogen transfers in newly imported species often result in establishment of infection in naturally susceptible indigenous hosts and may lead to the adaptation of pathogens to a new range of hosts. Due to their inherent genetic variability, rapid rate of replication, and common occurrence as low-level latent infections in apparently healthy animals, the transfer of viral pathogens is of particular concern. However, during the past decade, powerful DNA-based molecular tools have become available to trace the origins and spread of infections in animal populations and monitor viral adaptation to new hosts. These methods have been widely applied to infections in terrestrial animals and humans (e.g. foot-and-mouth disease in Europe, West Nile virus in the USA, HIV globally) but there has been quite limited application to aquatic animals. This approach, which has become known as molecular epidemiology, uses selected genetic markers to distinguish individual viral isolates. Accumulating mutations that occur as viruses spread through animal or human populations can be used to determine the relationship between isolates and the patterns of pathogen spread.

Viral disease

The Taura Syndrome Virus (TSV), which was initially identified on *P. vannamei* shrimp farms near the Taura River in Ecuador in early 1992, caused severe production and economic losses to the shrimp sector in the Americas, and remains as a major constraint to the sectoral development. Similarly, White Spot Syndrome Virus (WSSV), which was initially identified on *P. monodon* in Mainland China and Taiwan province of China, severely affected the Asian shrimp industry, and subsequently spread to Americas affecting *P. vannamei* production systems.

Figure 2
Exports of shrimp (mt) from Ecuador 1979-2002 and environmental/disease events
(Source: CNA website)



Although there is no evidence yet that TSV has spread to the major indigenous farmed shrimp species (*P. monodon* and *P. chinensis*) there has been a report of infection in wild metapenaeid shrimp in Taiwan province of China and an accompanying genetic adaptation of the virus. As a highly mutable RNA virus, TSV is particularly suitable for molecular epidemiological studies that, at this early stage of pathogen establishment, could be applied to trace the spread, adaptation and impact of the virus on indigenous farmed and wild crustaceans in the region. The methodology could also be applied to the detection and monitoring of other pathogens, particularly viruses that may be introduced with the species.

In Asia, first Yellowhead Virus (YHV) from 1992 and later White Spot Syndrome Virus (WSSV) from 1994 caused continuing direct losses of approximately $1 billion per year to the native cultured shrimp industry. In Latin America, first Taura Syndrome Virus (TSV) from 1993 and later, particularly, WSSV from 1999 caused direct losses of approximately $0.5 billion per year after WSSV (Figure 2). Ancillary losses involving supporting sectors of the industry, jobs, and market and bank confidence put the final loss much higher.

It is widely believed that these three most economically significant viral pathogens (and a host of other pathogens) have been introduced to the Asian and Latin American countries suffering these losses through the careless introduction of live shrimp stocks. Except for China, most Asian countries have legislated against the introduction of *P. vannamei* due to fears over the possibility of importing new pathogenic viruses and other diseases from Latin America to Asia.

Table 4. Hatchery and PL production for all shrimp and *P. vannamei* in Asian countries

Country	*P. vannamei* Maturations	*P. vannamei* Hatcheries	Other Shrimp Hatcheries	Total shrimp PL Production (million PL/mo)	*P. vannamei* PL Production (million PL/mo)
Mainland China	?	1,959	1,893	56,375	9,900
Taiwan province of China	20	150	250	754	644
Thailand	20	26	2,000	3,700	1,200
VietNam	9	9	4,800	1,600	90
Philippines	0	0	250	200	0
Indonesia	?	15	300	?	?
Malaysia	5	10	95	200	50
India	0	3	293	600	2
Sri Lanka	0	0	80	22	0
Pacific Islands	0	0	9	101	0
Total	**54**	**2,172**	**9,970**	**63,552**	**11,886**

Note: All data is for 2002

Many governments have allowed importation of supposedly disease free stocks that are available for this species from the USA. The encouraging trial results, the industry-perceived benefits, including superior disease resistance, growth rate and other advantages, allied with problems controlling the imports from other countries, has lead to the widespread introduction of this species to Asia, primarily by commercial farmers. Unfortunately, importation of cheaper, non-disease free stock has resulted in the introduction of serious viral pathogens (particularly TSV) into a number of Asian countries, including Mainland China, Taiwan province of China, Thailand and Indonesia, and possibly more. There are now many hatcheries established in Asia that are producing postlarvae for stocking (Table 4), although the original sources of the stock and their current health status are quite uncertain. What can be assumed is that many of the hatcheries are not able to maintain their stocks as SPF and invariably they become infected with local virus disease and quite possibly with the disease that are typical to the species when in south America (*e.g.* Taura). This is partly due to private sector hatcheries being unaware of the requirements for maintaining clean stocks and partly dues to corner cutting due to the rising demand for postlarval *P. vannamei.*

Biodiversity and impacts on wild stocks

Although TSV does not seem to have affected the indigenous cultured or wild shrimp populations, insufficient time and research has been conducted to prove this. TSV is also a highly mutable virus, capable of mutating into more virulent strains, which are able to infect other species. In addition, other viruses probably imported with *P. vannamei*, for example a new LOVV-like virus, have been implicated in actually causing the slow growth problems currently being encountered with the culture of the indigenous *P. monodon*. There remain many unanswered questions regarding the possible effects of introduced species on other cultured and wild shrimp populations in Asia.

At present there is still no available information regarding whether *P. vannamei* has established in the wild and if so, the effect of its interaction with existing crustacean species. For this reason there has been caution on the part of many Asian governments. However, this caution is not shared by the private sector, which has been bringing in stocks of illegal and often disease carrying *P. vannamei* into Asia from many locations. The commercial success of these introductions, despite disease problems has allowed the development of substantial culture industries for these species within Asia, so that there is effectively little ability to control the importation of *P. vannamei* and development of this new feature of the cultured shrimp sector in Asia.

6. International efforts and the history of import control.

The introductions of *P. vannamei* to non-native areas of the Americas and lately to Asia, have had a significant positive effect on the production capacities of the countries involved. This is probably the first time that this has ever been recorded with cultured shrimp. Despite the establishment of viable shrimp culture in many countries with this species, there are potential negative impacts that are emerging.

SPF "supershrimp" *P. stylirostris* have also been experimentally introduced to many Asian countries (including Brunei, Taiwan province of China, Myanmar, Indonesia and Singapore) from secure breeding facilities in Mexico and the US. These introductions began in 2000, but have yet to make a major impact on the culture industries in those countries (with the exception of a small industry in Brunei), but without notable problems so far. *P. stylirostris* was also introduced into Thailand and Mainland China in 2000, but has yet to make much impact there either.

Although incompletely understood, it is now clear that many of the introductions of trans-boundary species have also been responsible for the introduction, establishment and spread of thousands of pathogen (viruses, bacteria and fungi) and parasite species into new geographic areas and hosts. Once established in natural waters (and often aquaculture facilities) and hosts, such pathogens are almost impossible to eradicate. In most cases, fishery managers and governments have not properly considered pathogen transfer when contemplating trans-boundary movements of aquatic animals, or have been slow to react to such introductions directly by the private sector either with or without approval.

With proper planning, it may have been possible to avoid introduction of these pathogens and there now exist a number of international codes of practice and guidelines to assist this process. These include international efforts lead by the:

- The World Trade Organization (WTO),
- The International Council for the Exploration of the Sea (ICES)
- The Office International des Epizooties (OIE)
- The food and Agriculture Organization of the United Nations (FAO) via the Code of Conduct for Responsible Fisheries (CCRF)
- Regionally through the latest initiative is the FAO/NACA Regional Technical Cooperation Program (TCP/RAS 6714(A) and 9605(A)) "Assistance for the Responsible Movement of Live Aquatic Animals", which led to the Asian Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals

(source: GAA website, FAO/NACA/OIE, 1998, Fegan et al., 2001).

Direct, involuntary importation of new pathogens with their imported hosts has been shown to have even less quantifiable problems including transfer of new strains of established pathogens specific to the host, the potential for interbreeding with, and displacement of, native species and unknown effects on the genetic diversity and ecology of native fauna. Each of these has the potential to cause unexpected and far-ranging adverse effects on host populations and commercial and sport fisheries, with accompanying severe socio-economic impacts on human populations.

Private sector initiatives

In some countries, the private sector has adopted best management practices (BMPs), which have helped prevent on-farm disease problems. Although governments have also assisted these efforts through the development of expertise, infrastructure and capacity for health management, shrimp culture and capture fisheries in most countries remain vulnerable to further introductions of trans-boundary diseases. There is much further work that can be done however, and this report includes recommendations as to what this might comprise.

The recent publication of a number of codes of conduct and management guidelines (BMPs) for the trans-boundary importation of exotic shrimp and their subsequent culture by amongst others, the WTO, ICES, FAO, the OIE, NACA, ASEAN, SEAFDEC and the GAA have clearly defined most of the issues involved. With the availability of SPF and SPF/SPR stocks of *P. vannamei* and *P. stylirostris* from the Americas, Asia has had the opportunity to decide whether to responsibly undertake such importations for the betterment of their shrimp culture industries and national economies, whilst avoiding the potential problems with viral diseases and biodiversity issues. However, a number of factors are described to have prevented this ideal situation from manifesting. Although many of the potential problems involved with trans-boundary movements of shrimp and their viral passengers is as yet unknown, the Asian governments must take responsibility for legislating control over this industry.

World Trade Organization (WTO)

Trade issues are governed under the terms of the World Trade Organization (WTO), the legal and institutional basis for the international trading system. The main objectives for the agreement were to ensure access to markets, promote fair competition and encourage development and economic reform. Aquacultural issues are covered specifically in the "Agreement on the Application of Sanitary and Phytosanitary Measures" (SPS, 1995) and the "Agreement on Technical Barriers to Trade" (TBT).

The SPS agreement attempts to prevent non-tariff trade barriers, based on harmonized international standards, guidelines or recommendations where they exist. However, individual governments may take more stringent measures, provided they have scientific justification (i.e. following an import risk assessment), or if it is shown that international standards do not provide sufficient risk protection. Problems with harmonization of standards may arise if for example, an importing country refuses permission to import product from a country with a new or notifiable viral disease and the exporting country does not have the mechanism to ensure the product is free from the virus. Under these circumstances, the WTO has agreed to help the exporting country with its testing procedures. Settlement of disputes bilaterally is encouraged, but the WTO has its own procedures and impartial bodies are available if this is not possible (Fegan, 2000).

Office International des Epizooties (OIE)

The Committee of Sanitary and Phytosanitary Measures is linked to the Paris-based Office International des Epizooties (OIE) that sets the international standards for animal health measures. Since 1988, in the area of aquatic animal health the OIE has the Fish Disease Commission (FDC) which is responsible for informing governments of the worldwide aquatic disease situation, coordinating surveillance and control measures possible, and harmonizing regulations for trade amongst member countries. The recently introduced standards for aquaculture are currently limited by the lack of knowledge regarding aquatic disease problems. However, the OIE is continually updating two important documents for aquatic animal health: the International Aquatic Animal Health Code (2002) and the Diagnostic Manual for Aquatic Animal Diseases (2000), which are available free of charge on the OIE website at http://www.oie.int and new versions are due to appear at the end of July, 2003.

International Council for the Exploration of the Sea (ICES)

A code of practice for introductions of non-indigenous marine organisms was set by the International Council for the Exploration of the Sea (ICES) in 1973 and revised in 1994 (ICES, 1995). These codes had recommendations in the following areas: Recommended procedures for deciding on importations of new species; Recommended actions once the introduction has been approved; Encouragement for prevention of unauthorized introductions; and Recommended procedures for introduced or transferred species already under commercial cultivation.

Food and Agriculture Organization of the United Nations(FAO)

FAO released a voluntary, but partly internationally legal Code of Conduct for Responsible Fisheries (CCRF) during the FAO Conference of 1995 (FAO, 1995). The CCRF was the result of four years of work following the International Conference on Responsible Fishing in Cancun, Mexico in May, 1992.

Article 9 of the code covers aquaculture development and Article 9.3.3 states that: "States should, in order to minimize risks of disease transfer and other adverse effects on wild and cultured stocks, encourage adoption of appropriate practices in the genetic improvement of broodstock, the introduction of non-native species, and in the production, sale and transport of eggs, larvae or fry, broodstock or other live materials. States should facilitate the preparation and implementation of appropriate national codes of practice and procedures to this effect".

FAO further issued the "FAO Technical Guidelines for Responsible Fisheries No. 5: Aquaculture Development" in 1997 to provide general advice in support of Article 9 of the CCRF (FAO, 1997).

Asia Regional Initiatives (NACA & SEAFDEC/ASEAN)

Based on Article 9.3.3 of the FAO CCRF, a set of regional guidelines were issued by FAO/NACA in 2000, and called the "Asia Regional Guidelines on Health Considerations for the Responsible Movement of Live Aquatic Animals". These guidelines were developed through three years of awareness raising and consensus building and were adopted by 21 participating countries in the Asia-Pacific region in Beijing in June, 2000.

The guidelines were further adopted by ASEAN Fisheries Working Group in Bali in 2001 as an ASEAN policy document and endorsed by the ASEAN/SEAFDEC Millennium Conference on Fish for People in 2000 in Bangkok (FAO, 2000, NACA/FAO, 2001, SEAFDEC, 2001).

Country level initiatives to control or restrict importation

Despite the existence of these codes, protocols and guidelines, the government and particularly the private sector in both Asia and Latin America continue to introduce new species with little consideration of potential disease consequences. They have thus generally been caught unprepared for the recent epizootic outbreaks involved with shrimp trans-boundary movements. Additionally, their immediate responses have been largely ineffective in preventing or reducing disease losses which may exceed $1 billion/year in direct production losses worldwide, and considerably more in total. Countries which have actively enforced importation bans, with some success include:

- Brazil, Venezuela and Madagascar (who have so far managed to exclude WSSV and YHV)
- Hawaii and the continental United States, who have managed to eradicate WSSV from their culture industry
- The Philippines, who managed to delay the onset of WSSV by 4-5 years (compared to the rest of Southeast Asia), but do have non-SPF *P. vannamei* despite a ban, and
- Sri Lanka, who have still not allowed even experimental importation of *P. vannamei*, for fear of TSV.

7. Reasons for the lack of success of regulations

Problems with shrimp import limitations
That the numerous codes and guidelines have been largely ineffective at preventing the spread of exotic shrimp and their viral diseases throughout the world is quite apparent. The sheer scale of the cultured shrimp industry and the fact that shrimp are not usually covered by existing livestock legislation on movements gives plenty of gaps for such movements to take place. The reasons for movements are varied and include the following:

Producer driven importation
In many cases, even though governments have implemented guidelines or laws regarding the importation of trans-boundary shrimp species, the private sector has gone ahead with such imports through smuggling, non-disclosure and exploitation of a lack of government control over such importation. Thus, although there may be good reasons for limiting imports and regulations in place, these have little chance of success in limiting imports unless the private sector can be convinced of their validity and importance.

Perception of benefits of introduced species
The largely private sector-led introductions are done, whether or not official restrictions are in place, due to the perceived benefits offered by the introduced species. Thus, in the case of *P. vannamei* introductions into Asia, the current perceptions that: *P. vannamei* are more disease resistant than the indigenous species (*P. monodon* and *P. chinensis*), SPF broodstock can be purchased that are free from disease, and that they are more able to tolerate high density, often low-salinity culture, are the main driving forces behind their introduction. Whether these perceived benefits (Table 2) are true or not is often irrelevant, particularly when Asian shrimp farmers are struggling to make money using their traditional native species. In this case, as has been seen in virtually all Asian shrimp-producing countries in the past few years, the perception of the private sector is that the potential advantages outweigh the disadvantages and so the importation are made.

Whether this perception is correct or not remains unproven. On the positive side, the Asian *P. vannamei* culture industry has seen a rapid expansion in the last few years, so that production of *P. vannamei* has surpassed that of traditional native cultured species in Mainland China, is rapidly approaching that level in Taiwan province of China and Thailand, and is gaining increasing importance in Vietnam and Indonesia (see Table 3). The generally downward trend in Asian shrimp production during the 1990s, due largely to disease problems with *P. monodon* and *P. chinensis*, has thus now been reversed with the introduction of the relatively more tolerant *P. vannamei*.

On the negative side, the introduction of *P. vannamei* into Asia has been accompanied by the importation of various viruses, including TSV (already causing losses in Mainland China, Taiwan province of China and Thailand) and LOVV (possibly responsible for the slowing growth rate of *P. monodon*) and probably others. The long term effects of these viruses is unknown, but precedents from introductions of shrimp and their viruses from Asia to Latin America (i.e. IHHNV in 1981 and WSSV in 1999) are known to have resulted in severe setbacks to the shrimp culture industry and the socio-economic status of many countries. Additionally, the associated impacts of trans-boundary introductions of shrimp have unknown, but possibly serious consequences for wild shrimp populations and genetic diversity.

8. Recommendations for control of movement and culture of shrimp

Since it is clear that the majority of Asian countries have already introduced *P. vannamei* (either legally or illegally) to some extent, there is now some determination to try and ensure that any negative impacts are minimized.

Some countries are considering enforcing their official bans and destroying all stocks found within their borders (i.e. the Philippines and Malaysia). Short of this difficult (and perhaps legally unenforceable) procedure, the species, and in most cases, its attendant viruses, will remain in most countries.

A more pragmatic approach would be the investigation and elimination of all stocks infected with known pathogens, followed by an opening of the borders only to certified disease-free stocks. This assumes that the testing of stocks for import and the necessary controls of this would be strengthened, since at the moment it is the inability to effectively control imports which has allowed the introductions so far. This approach at least offers a working solution to the reality that *P. vannamei* is already present in many countries and being cultured at significantly economic levels in several. This also allow countries to take advantage of the potential benefits offered with this exotic species and would encourage a more responsible approach to the issue of shrimp movements and disease in the region, what is certain, is that blanket bans on the importation of species (such as *P. vannamei*) which are desired by the commercial sector are ineffective at preventing their introduction, under the current conditions in Asia.

Many recommendations regarding the health implications of the importation of exotic shrimp species (and their attendant pathogens), and their sustainable culture have recently been published. The following list draws heavily from the review made on the management strategies for major diseases in shrimp culture, based on a workshop held in Cebu, Philippines in 1999 (WB/NACA/WWF/FAO, 2001). The recommendations have been modified to focus on the issues involved with the trans-boundary importations of *P. vannamei* and *P. stylirostris* in Asia:

Legislation, Policy and Planning

- Develop improved legal frameworks, monitoring systems and enforcement capabilities to control and register importation and culture of exotic shrimp species
- Increase interaction between planners, policy makers, industry and other stakeholders to discuss strategies (and their application) for practical approaches to environmentally friendly and sustainable farming of exotic shrimp species
- Recognise in legislation the differences between "soft laws", codes and guidelines, and regional or international agreements and WTO "hard laws"

- Legislate penalties for beaches of legislation or quarantine and illegal activities such as smuggling, examine the issue of liability
- Develop and/or apply "best practices" for management of the shrimp industry based on continuous refinements of the FAO CCRF and similar guidelines on aquaculture development. This should include incorporation of quality assurance programmes (HACCP) into all aspects of the shrimp culture system
- Develop government infrastructure and industry liaison and registration of aquaculture facilities, so that codes of practice can be developed and followed, certifications or accreditation made, expertise in disease control identified and communication and awareness raised for the benefit of both parties
- Begin to regionally harmonize and implement Import Risk Analysis (IRA) to help prevent disease transmission. Training officials in the IRA process should be given priority
- Implement, and if necessary, design, environmental Impact Assessments (EIA) that take account of disease transmission issues with imported species
- Formulate national policies recognizing the importance of shrimp farming as a contributor to national development and assisting its development
- Formulate plans for comprehensive shrimp health management strategies using existing and novel approaches to correct problems in the environment, animal and pathogen
- Develop contingency plans and provide financial, technical and educational assistance for farmers suffering from disease outbreaks
- Enforce coastal area management regulations of relevance to shrimp farming
- Critical analysis of approval process for shrimp farms farming exotic species

Regional and International Cooperation

- Member states must advise OIE of any outbreaks of notifiable pathogens
- Link national diagnostics and disease control systems with other countries' networks to strengthen regional cooperation
- Establish a regional disease information network/website and a timely disease reporting system
- Organize regional annual meetings and workshops on shrimp health management for dissemination of information
- Establish data base of facilities offering certified disease-free SPF and resistant SPR stocks
- Give priority to collaboration between Latin American and Asian regions for cross-fertilization of ideas
- Recognise and identify the roles and inputs of NGOs

Disease Management Issues

- Establish national reference pathology labs to inter-calibrate with, and assure the quality of, private disease labs, and collaborate with the existing OIE reference labs
- Initiate Quality assurance programmes, including standardization of techniques and training in disease diagnosis labs to ensure their utility in the control of disease transmission
- Require that all facilities exporting shrimp have a minimum 2 year disease free status, are certified as such and can submit independent, qualified certification of their status
- Submit properly collected samples of imported shrimp to certified disease diagnosis laboratories for assurance of disease-free status, whist maintaining shrimp in biosecure quarantine facilities before release into the environment
- Conduct co-habitation trials of all imports with indigenous shrimp species to prevent the entry of unknown pathogens that pose high risks to local species

Research and Development

- Fund programmes to investigate methods of combating disease threats (with public/private sector cooperation)
- Investigate advantages and disadvantages of exotic shrimp for the culture industry of each country to determine its suitability for import
- Establish closed cycle breeding programmes to produce high quality SPF and SPR seed used for stocking ponds for both exotic and indigenous species
- Identify all potential viral pathogens and develop specific and sensitive tools for their detection appropriate for both lab and farmer level
- Research case-specific farming systems for each species so that it can be utilized optimally appropriate to local conditions
- Establish programmes to monitor aquatic environments in and around shrimp farming areas, including effects of culturing new species on wild populations
- Conduct routine analysis on the effects of new viruses on imported and indigenous hosts through cohabitation studies so that any effects or changes of viral pathogenicty can be monitored, and measures for its control investigated
- Conduct routine monitoring of wild shrimp populations for all pathogenic viruses, including an assessment of which species develop the disease and which act as carriers, with attempts made to discover the source of any contamination
- Assess the relative risk factors involved with each potential vector of shrimp pathogens to assist development of more appropriate intervention strategies for disease control
- Evaluate viability of alternative shrimp farming systems (i.e. utilizing low-salinity and/or inland farming areas and high density, low impact culture systems)
- Investigate shrimp production and health management capabilities and practices to determine suitable codes and guidelines for culture of exotic species
- Investigate best methods for dissemination of information pertaining to importation and management of exotic shrimp species
- Develop epidemiological approaches to disease management
- Evaluate water treatment methods for their ability to reduce disease risk
- Develop simple, low-cost methods of reducing exposure to disease carriers
- Evaluate the effectiveness of green water and shrimp/fish polyculture techniques for reducing disease outbreaks

Infrastructure, Capacity building and Training

- Establish a network of collaborating and cross-referencing disease diagnosis laboratories with state of the art equipment and trained manpower
- Consider reinvestment of export profits to improve health management capabilities
- Develop biosecure high-health maturation systems and hatcheries for exotic and indigenous species with functional quarantine systems for holding imported animals whilst they are screened, and training facilities/extension for the local farmers
- Develop a programme for the culture and genetic selection of exotic and indigenous species to aid development of improved broodstock with desirable culture characteristics, and training of farmers/extension agents in this technology
- Allocate the necessary equipment, personnel, training and travel required for disease diagnosis, interpretation of test results, and assessment of shrimp health management practices at laboratory and farm level
- Where required, provide overseas training or seminars from experts for government employees, trainers, extension officers and farmers on the techniques required to produce exotic species sustainably
- Improve information dissemination and increase farmer awareness of issues involved with the importation and culture of exotic shrimp so that farmers have the facts and can clearly understand the potential risks and benefits involved. Collaboration

between farmer's associations and the relevant government agencies would assist this process

- Establish databanks on all shrimp farms, perhaps using GIS technology for effective regulation, assessment, monitoring and law enforcement
- Promote training in the epidemiology of major shrimp diseases to improve awareness and develop practical health management schemes at farm, national and regional levels

Industry Management and Technological Requirements

- A series of guidelines for health management in shrimp hatcheries and growout ponds were made at the Workshop on Management Strategies for Major Diseases in Shrimp Aquaculture in the Philippines in 1999 (WB/NACA/WWF/FAO, 2001).
- These were used as a basis for a subsequent Latin America/Asia inter-regional meeting on shrimp diseases funded by APEC, held in Mexico in 2000.
- Out of this meeting a report entitled "Technical Guidelines for the Management of Health and Maintenance of Biosecurity in White Shrimp *Penaeus vannamei* Hatcheries in Latin America" was produced (FAO, in press).

Industry based BMP recommendations

- The Global Aquaculture Alliance (GAA) has also produced and is distributing a set of "Codes of Practice for Responsible Shrimp Farming" and operating procedures for shrimp farming based on a 2001 survey of World shrimp farming practices.
- These guidelines were formulated to assist the development of national and regional codes of practice to help the shrimp farming industry and are available from the GAA website
- For example, the GAA Shrimp health management code of practice has, as its purpose, to promote shrimp health management as a holistic activity in which the focus is on disease prevention instead of disease treatment. They state that authorities on shrimp health management recognize that stress reduction through better handling, reasonable stocking densities, good nutrition, and optimal environmental conditions in ponds can prevent most infectious and non-infectious diseases.
- Also, treatment should be undertaken only when a specific disease has been diagnosed. In addition, effective measures must be taken to minimize the spread of diseases between farm stocks and from farm stocks to natural stocks.