Preliminary risk assessment of Pacific whiteleg shrimp (	extit{P. vannamei}) introduced to Thailand for aquaculture

Senanan, W.\textsuperscript{1}, Panutrkul, S.\textsuperscript{1}, Barnette, P.\textsuperscript{1}, Chavanich, S.\textsuperscript{2}, Mantachitr, V.\textsuperscript{1}, Tangrock-Olan, N.\textsuperscript{1}, and Viyakarn, V.\textsuperscript{2}

1. Department of Aquatic Science, Faculty of Science, Burapha University, Chon Buri 20131, Thailand; 2. Department of Marine Science, Chulalongkorn University, Bangkok, Thailand

Marine shrimp (Penaeus spp.) are important commodities for several Asian countries, including Thailand (Briggs et al., 2005). Thailand had been one of the largest exporters of Black tiger shrimp (P. monodon) for decades until the outbreaks of viral diseases (white spot syndrome virus, WSSV; and yellow head virus, YHV) in the early 1990s. In response, low salinity shrimp farming techniques were developed and quickly applied in agricultural areas, especially rice fields (Szuster, 2001; Tensosgrusmee, 2000). Further disease outbreaks, poor growth performance and declining prices for 	extit{P. monodon} led to the introduction of Pacific whiteleg shrimp (P. vannamei) to Thailand in 1998 (Briggs et al., 2005). 	extit{P. vannamei}, a species native to the Pacific coasts of Central and South America (Perez Farfante and Kensley, 1997), is known for its tolerance to a wide salinity range and its fast growth rate in brackish water (Holthuis, 1980).

Aquaculture of 	extit{P. vannamei} has rapidly expanded because of the species’ fast growth, low incidence of native diseases and availability of domesticated strains. The annual production of 	extit{P. vannamei} in Thailand has surpassed 	extit{P. monodon} every year since 2004. In 2007, an estimated 441,450 tons of 	extit{P. vannamei} were produced, representing more than 99% of the total marine shrimp production in Thailand (DOF, 1999-2005). This rapid expansion has facilitated the release of farmed 	extit{P. vannamei} into natural environments (Senanan et al., 2007).

While aquaculture promises economic and social benefits, aquaculture escapes can pose ecological risks to the receiving aquatic environments (e.g., De Silva 1989; Naylor et al. 2001; Miller et al. 2004; De Silva et al. 2006). Some ecological impacts, such as reducing aquatic biodiversity or spreading alien pathogens, may undermine the sustainability of aquaculture and small-scale fisheries. By incorporating science-driven ecological risk assessment prior to new introductions and integrating a risk monitoring program, we may prevent such undesirable outcomes. This paper presents data relevant to ecological risk assessment of 	extit{P. vannamei} culture in Thailand, generated by studies conducted during 2005-2007 by our research team. This three-year research program, funded by the National Research Council of Thailand, used a case study of 	extit{P. vannamei} introductions to the Bangpakong River and along the east coast of Thailand.

The research questions followed the risk assessment framework, consisting of the following steps: (1) identification of hazards (i.e., events leading to undesirable consequences), (2) assessment and prediction of the likelihood and severity of the harms (frequency/exposure analysis and harm/effect analysis), and (3) characterisation of risk (i.e., combined probability of the likelihood of hazard realisation and severity of harms). Our research program focused on step (1) and the beginning of step (2). In our context, hazards include (1) the escape of 	extit{P. vannamei} from farms to natural ecosystem; (2) the survival of escaped 	extit{P. vannamei}; and (3) the reproduction of escaped 	extit{P. vannamei}.

We attempted to address two types of impacts, the spread of Taura Syndrome Virus (TSV), an alien pathogen carried by 	extit{P. vannamei}, and (5) the ability of 	extit{P. vannamei} to compete for food with local species.

We chose the Bangpakong River, one of the largest and most important estuary ecosystems in eastern Thailand, as a case study because (1) its watershed harbours the largest area of shrimp farming in eastern Thailand (8,900 hectares
of Chacheang Sao province in 2004, DOF 1999-2004), (2) its estuarine conditions provide viable habitat for escaped P. vannamei, and (3) already installed stationary stow nets within the main channel are quite effective in capturing wild shrimp, enabling us to obtain escaped P. vannamei from the wild.

Our research program has generated the first set of quantitative data that feeds into preliminary risk analysis of the releases of P. vannamei. These data answered the following questions: how many P. vannamei have escaped? Can escapees survive in the natural environment? Can escapees establish a natural population? What is the extent of geographic spread of the alien pathogen, Taura Syndrome Virus (TSV)? Can P. vannamei potentially compete with native shrimp species?

**How many P. vannamei have escaped?**

Results from Manthachitra et al. (2008), Senanan et al. (2007) and Senanan et al. (in press) indicated that P. vannamei has escaped from farms to the Bangpakong River and the numbers of P. vannamei sampled in the river positively correlated with the location and area of shrimp ponds. Mantachitra et al. (2008) used remote sensing and a geographic information system (GIS) to estimate location and total area of shrimp ponds (active, inactive, and abandoned ponds) in the Bangpakong River watershed and found that most ponds were located within 5 km of the river. During 2005-2007, the authors’ estimates of active pond area ranged from 88.72 km² in 2007 to 116.81 km² in 2005. The highest concentration of shrimp ponds were found in the middle section of the Bangpakong River, including three districts of Chachoeng Sao province (Bang Khla, Mueang Chachoeng Sao and Ban Pho). Survey of marine shrimp populations in the Bangpakong River during the same period (Senanan et al., 2007, in press) confirmed the presence of P. vannamei in the river (Figure 1). Mean proportion of P. vannamei relative to all penaeid shrimp per net per year (all stations combined) ranged from 0.005 (June 2005) to 0.16 (January 2006), with the highest abundance detected in 2006. The presence of P. vannamei in the river may be a consequence of pond water releases during the intense farming activities of 2005. In addition, Barnette et al. (2008) and Senanan et al. (in press) detected high occurrence of TSV in sub-adult P. vannamei caught from the river. Their results might indicate the intentional release of diseased individuals into the river.

Our studies were not designed to address the issue of escapes of larval life stages from hatcheries, and the magnitude of this source remains unknown. However, hatcheries are highly concentrated in the Bangpakong watershed. The issue of larval escapes from hatcheries remains an important concern that will require additional research and monitoring.

**Can escapees survive the natural environmental conditions?**

Results from Panutrakul et al. (in press) and Chavanich et al. (2008) indicated that P. vannamei escapees can likely survive the environmental conditions of the Bangpakong River and its river mouth. Panutrakul et al. (in press) conducted toxicological experiments to evaluate the physiological limits of larvae and juvenile of P. vannamei and P. monodon to extreme salinity and pH changes. The authors found that both species can tolerate a wide range of salinity and pH. For both life stages, P. vannamei could tolerate a wider range and more extreme changes of salinity and pH than P. monodon (Figure 2). The data suggested that both life stages of P. vannamei could adapt to estuarine conditions of the Bangpakong River where water quality, especially salinity, can fluctuate dramatically. During the dry season (December to May), the salinity in the Bangpakong River is within the tolerance limits of P. vannamei. Although the salinity in the river may approach zero at most sites during the wet season (June to November), P. vannamei would be able to migrate to the river mouth. Panutrakul et al. (in press) detected an increase in abundance and size over time of P. vannamei captured in the river and near the river mouth.

Chavanich et al. (2008) analysed stomach contents of wild-caught P. vannamei and local shrimp species. They found that P. vannamei consumed the same diet types in similar proportions as local shrimp species. The diet types included phytoplankton, appendages of crustaceans, remains of sea grass leaves, macrophytes, and small mollusc shells and unidentified detrital material (Figure 3). Stomach content analysis indicated that P. vannamei can utilise food resources available in the Bangpakong River and these resources were shared between P. vannamei and local shrimp species.

![Figure 3](image)

**Can escapees establish a natural population?**

The maturity of P. vannamei escaped from farms to natural environments is another important factor determining their ability to establish a feral population. Senanan et al. (2008) compared the histology of gonads of wild-caught P. vannamei and captive P. vannamei of known ages. Captive individuals could develop mature gonads at 11 months after post larvae 15 (ovaries contained 50% mature oocytes; testes contained 80% mature sperm cells). They did not find sexually mature individuals in the wild although some wild-caught males larger than 19 g contained a small percentage of mature sperm cells. We still cannot conclude that escapees can establish a feral population. However, this study might have undersampled sexually mature individuals due to inappropriate sampling sites and timing. This issue remains important for
further investigation. A monitoring program in off-shore areas may provide opportunities for us to obtain sexually mature individuals.

What is the extent of geographic spread of the alien pathogen, TSV?

Using PCR and immunological analyses, Barnette et al. (2008) examined the occurrence of TSV and two local viruses (WSSV and YHV) in populations of P. monodon adults in the Gulf of Thailand, populations of local shrimp species and P. vannamei in the Bangpakong River. The data suggested that TSV has already spread into the Bangpakong River and the Gulf of Thailand. The authors detected the presence of TSV in P. monodon adults, local shrimp species of the Bangpakong River (ten species, namely Penaeus monodon, P. semisucatus, P. merguiensis, Metapenaeus brevicornis, M. affinis, M. tenuipes, Parapenopsis hungerfordi, Macrobrachium rosenbergii, and two other species belonging to the Family Caridae), and wild-caught P. vannamei (Figure 4). The authors also detected TSV in green mussel (Perna viridis), blue swimming crab (Portunus pelagicus) and Asian seabass (Lates calcarifer). TSV appeared to be more widespread in dry seasons compared to wet seasons. In addition, Barnette et al. (2008) showed that all three viruses can be horizontally transmitted among shrimp species (P. vannamei, P. monodon and Macrobrachium rosenbergii).

Can P. vannamei potentially compete with native shrimp species?

Chavanich et al. (2008) conducted food competition experiments pairing P. vannamei with one of two local shrimp species (P. merguiensis and Macrobrachium sp.) or blue swimming crab (Portunus pelagicus) (see also in Panutrakul et al., in press). The authors concluded that P. vannamei could potentially compete for food with both local shrimp species. In aquaria, P. vannamei often approached food items faster than the local species. Although this study may not represent a natural situation, as only two individuals were paired in each aquarium, the findings raise important issues about food competition and may serve as a starting point for further ecological studies that address crucial ecological interactions between an alien species and the receiving biotic communities.

Although our research has both retrospective and predictive elements of risk assessment as P. vannamei is already present in Thailand, the approach used and the data generated from our research can provide guidance for many countries that plan to introduce P. vannamei or other alien aquatic species for aquaculture. Furthermore, the data raise some important management issues for countries that have already introduced this species for aquaculture. Some recommendations based on these data include the following:

1. Implement preventative measures to reduce the numbers of escapes from shrimp farms and hatcheries. In addition, releasing pond water containing diseased shrimp should be prohibited.

2. Sanitise ponds containing diseased individuals before releasing pond water into natural systems. This strategy will reduce the input of both pathogens and escapees into natural ecosystems.

3. Strengthen the screening requirements for pathogens in broodstock. Tighter import regulations may also help reduce the spread of pathogens from aquaculture facility to natural ecosystems.

4. Discourage polyculture of P. vannamei with local shrimp species because pathogens can transfer among them. This may lead to enhanced virulence of TSV in local shrimp species.

Figure 4. Boxplots of 96-hour LC50 of postlarvae and juveniles of P. vannamei and P. monodon at (a) low salinity (0-20‰), (b) high salinity (30-40‰), (c) low pH (4.5-6) and (d) high pH (8.6-9.6).
5. Establish a monitoring program for the presence of *P. vannamei* and TSV in the wild, especially the off-shore areas. Such a program will allow for the detection of the geographic spread of escapees and some of their impacts.

6. Communicate the risks associated with alien species to shrimp farmers, fishermen and other relevant parties to help prevent future escapes. These parties may also take part in a network to monitor realised impacts of *P. vannamei*.

7. Continue to support relevant research, including long-term monitoring of population establishment and realised impacts of *P. vannamei*, the development of risk decision-making tools, and the development of risk reduction/mitigation strategies.

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References


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**Figure 5.** Diet types found in gut content of *P. vannamei* and local shrimp species of the Bangpakong River.

**Figure 6.** Percentage occurrence of Taura Syndrome Virus (TSV) in shrimp species local to the Bangpakong River, wild *P. monodon* adults and wild-caught *P. vannamei* during the dry and wet seasons of 2005-2007.
Farmer profile

Mr Hung is the fourth of six siblings of a fisher family of the Mekong Delta. He was educated up to the 5th grade when he decided to continue the traditional family livelihood of fishing. Around 1974 as an 18 year old he decided to catch catfish fingerlings in the flood period plains, and rear them in a wooden cage of 6 x 12 m with stainless copper mesh on the sides. He continued to feed the stock with a mixture of rice bran, morning glory and broken rice, depending on availability and affordability at the time, when the fish reached about 1.2 kg in 11 months. He sold the produce at local markets in VinLong, CanTho and other nearby places. Through this practice, over the subsequent years his production annual production increased to about 15 t.

Mr Hung was inquisitive and was always on the look out to improve his farming practice. He began to notice that if the cage bottom touched the soil, the stock grew better and was less prone to disease, and the flesh was also white. This simple observation made him believe that tra catfish would perform better in earthen ponds than in cages, and that was the beginning of pond farming of catfish in the Mekong Delta!

By 1984, within a decade, Mr. Hung had expanded his practice to 2 ponds (10 x 10m) and 3 cages, and a production of 20 tonnes per year. By 1990 he had 10 cages and 3 ponds, each of 1 ha, obtained through a lease from the government - areas not suitable for rice cultivation and achieve a production of 150 tonnes per year. Up to this stage Mr Hung would procure wild caught fingerlings from the wild in Cambodian waters, himself using his fishing skills, and his farmed produce was sold for around 3,200 to 3,400 VND/ kg ($US 0.31 – 0.32), fetching approximately 4,000 VND/ kg ($US 0.38) in Ho Chi Min City.

During the period 1991-95 he improved the practice to obtain three crops per 24 months, and a production to 5,000 tonnes per year, and proceeded on to improve further and further when by 2000 he was able to produce 10,000 tonnes in 5 ponds and 10 cages. In 1993, as the catfish exports began to occur Mr Hung commenced selling his produce to processing plants. Mr. Hung began to further expand his farming activity and by 2005-06 he was able to produce nearly 60,000 tonnes per year, with a concurrent expansion of culture pond area to 200 ha, through land leases, and thus became one of the most important players in the catfish farming sector in the Mekong Delta.

Mr. Hung’s endeavours did not stop at achieving this incredible level of production of 60,000 tonnes per year. He decided to venture into the processing sector, where he established a processing plant, which currently is capable of handling 100 tonnes of raw material per day. The plant employs 1,900 people of which 90% are women, empowering rural households and communities. Mr Hung plans to have a second processing plant functioning by February 2010, and he continues to forge ahead.

The simple lesson learnt is that human endeavour, an open mind, hard work, determination and the ability to recognize emerging opportunities enables one to reach great heights, bringing reward to the individual, but even more importantly bringing wealth and prosperity to the community - empowering the poor and the needy. Mr. Hungs’ personal wealth is secondary to the wealth, empowerment and happiness he has brought to the community!!!

Based on the translation of an interview with Mr Hung October 2009 in Dong Thap, Vietnam.

Endurance or opportunity: Recognition is the key to success; the story of a catfish farmer of the Mekong Delta

From a humble beginning to the top of the league of the catfish farming sector

It was one of the most intriguing encounters when the extremely shy, self-made catfish farmer Trang Hung, the President of the HungCa Co Ltd. from Dong Thap province in the Mekong Delta, agreed to enlighten us with his most incredible life story which over a 35 year period has made him one of the major players in the catfish farming sector in the Mekong Delta.

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