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

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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 *P. monodon* led to the introduction of Pacific whiteleg shrimp (*P. vannamei*) to Thailand in 1998 (Briggs et al., 2005). *P. vannamei*, a species native to the Pacific coasts of Central and South America (Perez Farfante and Kelsley, 1997), is known for its tolerance to a wide salinity range and its fast growth rate in brackish water (Holthuis, 1980).

Aquaculture of *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 *P. vannamei* in Thailand has surpassed *P. monodon* every year since 2004. In 2007, an estimated 441,450 tons of *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 *P. vannamei* into natural environments (Senanan et al., 2007).

While aquaculture promises economic and social benefits, aquaculture escapees 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 *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 *P. vannamei* introductions to the Bangpakong River and along the east coast of Thailand. The research focused on the following aspects: (1) the quantity of escapees from farms located in the Bangpakong River watershed, (2) the ability of escapees to survive natural conditions, (3) the reproductive capacity of escapees, (4) the spread of Taura Syndrome Virus (TSV), an alien pathogen carried by *P. vannamei*, and (5) the ability of *P. vannamei* to compete for food with local species.

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 *P. vannamei* from farms to natural ecosystem; (2) the survival of escaped *P. vannamei*; and (3) the reproduction of escaped *P. vannamei*. We attempted to address two types of impacts, the spread of TSV and food competition. Senanan et al. (in press) provided detailed description of the framework and illustrated its use for the case of *P. vannamei* in Thailand.

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 Chachoenfsao 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.
vannami 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
Chachoenfsao province (Bang Khla, Mueang Chachoenfsao
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.
vannami 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
cought 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.

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 under-
sampled sexually mature individuals due to inappropriate
sampling sites and timing. This issue remains important for

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Figure 3. P. vannamei abundance relative to the total number of
Penaeid shrimp species (proportion of P. vannamei per net) in
the Bangpakong River during January 2005 – November
2006. * and O indicate extreme values and outliers,
respectively. (Data reported in Senanan et al. (2007) and
Panutrakul et al. (in press)).
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. semisuscatus*, *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).](image-url)
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.

Acknowledgements

The authors would like to acknowledge the technical assistance of personnel at the Department of Aquatic Science, Burapha University; the Department of Fisheries, Ministry of Agriculture and Cooperatives and local fisherman. The research was funded by the National Research Council of Thailand (research program “aquaculture management strategies for the Pacific whiteleg shrimp (Litopenaeus vannamei) in the Bangpakong River basin and the east coast of Thailand. Burapha University, Chon Buri. (in Thai with an English abstract). Briggs, M., Funge-Smith, S., Subasinghe, R.P., and Phillips, M. 2004. Introductions and movement of *Peneaus vannamei* and *Peneaus stylirostris* in Asia and the Pacific. RAP publication 2004/10. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific, Bangkok. 70 pp.


**References**

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.

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 achieved 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 Minh 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.