Chapter

Ecological and Social Impacts of Aquacultural Introduction to Philippines Waters of Pacific Whiteleg Shrimp *Penaeus vannamei*

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Abstract

The importation of exotic aquatic species for aquaculture has become a world-wide practice. Culturing the Pacific whiteleg shrimp, *Penaeus vannamei*, outside its natural geographic range, however, can cause many problems. We evaluated the implications of the aquacultural introduction of *P. vannamei* to the Philippines waters both on ecological and social aspects. Several questions were answered and discussed based on literature, scientific details, reflections on personal experience and their relevance to aquaculture of the *P. vannamei* in the Philippines to evaluate the ecological impacts while social impacts were discussed only based on literature. Findings revealed the escapes of *P. vannamei* from aquaculture production facilities of several countries including the Philippines. Consequently, the ability of *P. vannamei* escapees to survive the natural environment could lead to ecological concerns such as resource competition, reproduction, and the spread of disease in the wild. On the other hand, the recent expansion of shrimp culture has resulted in social conflicts with other resource users. Therefore, this review shows the negative implications on the aquacultural introduction of Pacific whiteleg shrimp *P. vannamei* in the Philippines both ecological and social aspect, and this heightens important management issues to ensure sustainable farming of the shrimp in the Philippines.

Keywords: exotic organism, intentional release, tolerance, propagule pressure, alien pathogen

1. Introduction

An exotic organism or a non-native organism is a plant or animal that has been transplanted by humans; they are usually perceived from a negative point of view [1]. The International Union for Conservation of Nature [2] describes Alien species (non-native, non-indigenous, foreign, exotic) a species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e., outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans), which includes any part, gametes, or propagule of such species that might survive and subsequently reproduce. On the other hand, Invasive alien species (IAS) are species whose introduction and/or spread outside their natural past or present distribution threatens biological diversity which occurs in all taxonomic groups, including animals, plants, fungi, and microorganisms, and can affect all types of ecosystems [3]. Generally, exotic species are regarded as IAS.

IAS is one of the five most important direct drivers of biodiversity loss and change in ecosystem services [4]. According to the Invasive Special Specialist Group, [5], IAS can interact with migratory species in several ways resulting in cumulative negative impacts, for example, as a threat on their breeding sites, on their stopover and wintering grounds, and during migrations. These impacts may result in local extinction or decline in population numbers as well as changes to migration patterns. IAS impacts native species (including migratory species) and their habitats through several mechanisms, including predation, habitat degradation (grazing, herbivory, browsing, rooting/digging and trampling), competition, hybridization, disease transmission, parasitism, poisoning/toxicity, biofouling, etc. IAS has resulted in major impacts on biodiversity at a global scale, where at least 39% of the species extinctions during the past 400 years are due to IAS [6].

The importation of alien or exotic aquatic species from other countries is continuing in the Philippines. Most of the importation is for aquaculture and the aquarium trade. Exotic species are either purposely or accidentally introduced in rivers and lakes which are inhabited by endemic and indigenous fish species. Most of these introductions have contributed negative impacts on freshwater/wetland ecosystems and have caused biodiversity loss [7, 8], while some introduced species have contributed a significant proportion to aquaculture in the Philippines [9]. In terms of such contributions, the Nile tilapia *Oreochromis niloticus* is next to milkfish *Chanos chanos* among the aquaculture species, followed by the big head carp *Aristichthys nobilis* [10].

There are 181 organisms (28 families) introduced of exotic aquatic species since the 1900s; however, 40 organisms have unknown records of introductions in the Philippines [11]. In 2018, the IUCN Invasive Species Specialist Group [12]'s Global Invasive Species Database (GISD) lists 84 alien species, 12 with bio status unspecified and 54 that are native to the Philippines. The Pacific whiteleg shrimp *P. vannamei* is not included in the list; however, published studies reported the risk of culturing the shrimp outside its natural geographic range. For intensively farmed *P. vannamei* in Indonesia, the final numerical score is 3.39 out of 10, where the presence of three red criteria (Habitat, Chemicals, Disease) results in an overall red "Avoid" recommendation. Red mark means that these items are overfished or caught or farmed in ways that harm other marine life or the environment [13].

P. vannamei [14] is native to the Eastern Pacific coast from the Gulf of California, Mexico to Tumbes, North of Peru [15]. In the Philippines, *P. vannamei* was imported from Panama in the 1970s and from Hawaii in 1990 [16, 17]. However, there was no documentation of these introductions because government regulations were not followed in most cases, and it was not known whether the exotic species introduced any new pathogens [18].

Risk can be defined as the likelihood of harm occurring as a result of an action or inaction [19]. Harm refers to the undesirable consequences to humans or components of a valued ecosystem [20]. However, Senanan et al. [21] argued that there is a challenge in analyzing the ecological risk of alien species because of difficulty in predicting the harm, estimating the likelihood of harm occurring and the severity of the harm. These parameters are species and ecosystem specific and are often difficult to measure. The analysis would describe the ecosystem components (abiotic and biotic) and relevant processes, life history characteristics of the alien species and the relevant interaction between the two, drawing on existing data and literature, as well as specific experiments and field surveys.

The presence of Pacific whiteleg shrimp *P. vannamei* in the Philippines has already reached more than five decades, and this raises risk and environmental concern. This is timely relevant to the theme of the book *Spatial Variability in the Environmental Sciences - Patterns, Processes, and Analyses* which covers the topics on migration, extinction, disturbance, restoration, contamination, conservation, pollution, revitalization, growth, and decline. Thus, this review paper aimed to determine the ecological and social impacts of aquacultural introduction to the Philippines waters of Pacific whiteleg shrimp *P. vannamei*. The preliminary risk analysis of the releases of *P. vannamei* guided with several questions reported by Senanan et al. [22] was adopted to evaluate the ecological impacts, while social impacts were evaluated based on literature. Guide questions include (1) "How many *P. vannamei* have escaped?", (2) "Can escapees survive in the natural environment?", (3) "Can escapees establish a natural population?", (4) "What is the extent of the geographic spread of the alien pathogen, Taura syndrome virus (TSV)?", and (5) "Can *P. vannamei* potentially compete with native shrimp species?". The questions were answered and discussed based on literature, scientific details, reflections on personal experience, and their relevance to aquaculture of the *P. vannamei* in the Philippines. Conclusions were formulated based on the interpreted findings of this review, and recommendations were made for sustainable aquaculture of *P. vannamei* in the Philippines.

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

There have been numerous reports of escapes from aquaculture production facilities into non-native waters. The presence of *P. vannamei* has been reported in Texas, South Carolina, and Hawaii, USA [23–28]; Thailand [29, 30]; Venezuela [31]; Brazil [32]; Puerto Rico [33]; Vietnam [34]; and Southern Gulf of Mexico coast [35]. In the Philippines, Briggs et al. [29] reported that a population of *P. vannamei* already exists in the wild through intentional release and escapes. The implementation to ban the importation of all live shrimp and prawn species of all stages except for scientific or educational purposes by the Bureau of Fisheries and Aquatic Resources (BFAR) in 1993 led to illegal importation in 1997 by private sector due to disease problems with the culture of *P. monodon*, and the regulations are known to have resulted in the dumping of PL *P. vannamei* into the wild in attempts to escape detection. Also, typhoons have also resulted in the liberation of *P. vannamei* from culture ponds into the surrounding sea. On average, 20 typhoons hit the Philippines every year, and some of the most destructive and deadliest typhoons include Yolanda (2013), Pablo (2012), Sendong (2011), Ondoy (2009), Frank (2008), Milenyo (2006), and Reming (2006) (http://bagong.pagasa.dost.gov.ph/). Based on the main author personal experience, *P. vannamei* has been sometimes a part of catch by local fisherman in Buguey Lagoon, Cagayan. Its presence in the lagoon is possibly due to the escape from the Dataj Aquafarm which is actively engaging in the grow-out of *P. vannamei* in four different locations in the municipality of Buguey and Camalaniugan with a total area 77.91 hectares. The lagoon serves as the main water source of the farms. More frequent flood incidence in the area is taking place especially during typhoons or heavy rains due to black sand mining that started in 2009 until 2013 that widens the mouth of the lagoon.

Through the years, the culture of *P. vannamei* in the Philippines is continuously growing even during the implementation of the shrimp importation ban from 1993 to 2006. In fact, about 700 hectares of *P. vannamei* illegal farms in Luzon have been reported in 2003 [36]. The ban was lifted in 2007 after experimental trials and a series of public consultation and hearings [37]. In 2008, there were 38 grow-out farms engaged in *P. vannamei* farming, and it increased to 53 farms in 2013 [38]. Additionally, based on the [39] master list of shrimp farms as of December 2013, the shrimp has been polycultures with fish (17 farms, 642.7 ha) and *P. monodon* (4 farms, 33.0 ha). In 2014, there were 27 accredited hatcheries that continually support the demand of seedling requirements of the shrimp [40]. As of August 31, 2019, however, there were already 40 accredited hatcheries and 545 grow-out farms of the shrimp with a total productive area of 7382.08 hectares [41–43]. The boom and rapid expansion of the shrimp aquaculture are expected because of its demand for both the local and global markets. With this continuous expansion of *P. vannamei* farming, it is possible that shrimp can be found in the different estuary or brackish water rivers in the Philippines wherein the hatcheries and grow-out farm's operations are found due to escapes. The probability of escapes is higher because out of the total farms in 2019, 331 farms with an area of 4144.19 hectares were operating extensive grow-out practices wherein old and not properly designed ponds are usually utilized. A small percentage of escapes per operation cycle could translate to significant numbers of individuals entering the ecosystem. According to Panutrakul et al. [44], the shrimp can enter estuary at various life stages including post-larvae (produced from hatcheries), juveniles, and subadults (cultured in ponds). As of 2019, however, no studies have been conducted in the Philippines to verify the presence of the shrimp in the wild.

In Thailand, floods in Surat Thani and Pranburi in 2003, for example, led to several million *P. vannamei* escaping to the coastal environment. Not surprisingly, the shrimp, therefore, has been reported in fisherfolk's catches on Andaman and Gulf of Thailand coasts. No detailed information on catches is available, but numbers have not been reported as large [29]. Similarly, an incident of escape was reported from farms to the Bangpakong River in Thailand [30, 45]. The study showed that the numbers of the shrimp sampled in the river positively correlated with the location and area of shrimp ponds. Manthachitra et al. [45] used remote sensing and a geographic information system (GIS) to estimate the 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. The presence of the shrimp was confirmed based on the survey of marine shrimp populations in the Bangpakong River during the same period conducted by Senanan et al. [30]. The 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 the shrimp in the river may be a consequence of pond water releases during the intense farming activities of 2005. In the Southern Gulf of Mexico coast, there is a first report of the presence of *P. vannamei* [35]. During a shrimp monitoring program survey conducted in this area, seven specimens were collected in the Carmen-Pajonal-Machona lagoons near La Azucena and Sanchez Magallanes in Tabasco, Mexico.

3. Can escapees survive the natural environmental conditions?

Pacific white shrimp *P. vannamei* is the most economically important species for aquaculture in extensive, semi-intensive, and intensive systems in many parts of the world [46, 47] due to several advantages compared with other cultured shrimps. These are largely associated with the ability to close the life cycle and produce broodstock within the culture ponds, rapid growth rate (at up to 3 g/week), tolerance of high stocking density (150/m^2 in pond culture, and even as high as 400/m^2 in controlled recirculated tank culture), tolerance of low salinities (0.5–45 ppt) and temperatures (15–33°C), lower protein requirements (20–35%) and therefore production costs, and high survival (50–60%) during larval rearing [29]. However, the question remains if they can survive in the natural environment wherein adverse conditions are present.

It can be assumed that *P. vannamei* escapees can survive the natural environmental conditions based from early reports [23–31, 34, 35]. For instance, a large number were released accidentally from a shrimp farm in Texas in 1991, and the escapees were caught up to 65 miles from the shore [48]. The presence of the shrimp in commercial catches in South Carolina was also reported in 1989 and 1990 [49]. On the other hand, Medina-Reyna [50] reported the growth and emigration of the shrimp in the Mar Muerto Lagoon, which is one of the largest nursing grounds for this species in Mexico. Reports were all related to the ability of the shrimp to tolerate a wide range of salinity. Recently, the study of Chavanich et al. [51] results indicated that *P. vannamei* escapees can likely survive the environmental conditions of the Bangpakong River and its river mouth. A toxicological experiment was conducted to evaluate the physiological limits of larvae and juveniles of *P. vannamei* and *P. monodon* to extreme salinity and pH changes [44]. Results showed 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*. 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. The shrimp is also capable of migrating to the river mouth; in times the Bangpakong River may approach zero salinity at most sites during the wet season (June to November). This eventually resulted in an increase in abundance and size overtime of the shrimp captured in the river and near the river mouth. More likely, this scenario already existed in Buguey Lagoon in Cagayan since the shrimp has been a part of fishermen catch in the area, and this could be true in other estuaries and rivers in the Philippines wherein the shrimp hatcheries and farms are located.

4. Can escapees establish a natural population?

According to CABI [52], the species itself is not considered a major threat to biodiversity and does not appear to have formed breeding populations. Briggs et al. [29] added that despite the fact that the species has been widely introduced, a comprehensive study of the literature carried out for this report and the information available from other countries in Asia and in the Americas did not find any evidence of the shrimp becoming established in the wild outside of its range (i.e., it may not become an easily "invasive" species). However, there is a need for further field research, as there was insufficient information available on the natural breeding habits of the shrimp to make any further assessment of this issue.

Understanding the biology of *P. vannamei* is vital in order to know whether this animal once escape can establish a natural population that is crucial to the environment. However, there is limited information on the biology of this animal and is neglected during the last two decades. According to Dugassa and Gaetan [53], *P. vannamei* lives in tropical marine habitats, and the adults of this species live and spawn in the ocean. However, the larvae and juveniles are usually found in inshore water areas such as coastal estuaries, lagoons, or mangrove areas. The shrimp females grow faster than the male of this species. The matured female weighing 30–45 g can spawn 100,000–250,000 eggs. The shrimp life cycle is very complex, and it usually takes around 1.5 years to complete the whole life cycle. The matured shrimp females spawn their eggs in the offshore waters [54], while fertilization occurs in the external environment [53]. However, the maturity of the shrimp escaped from farms to natural environments is an important factor in determining their ability to establish a feral population [22]. A study has been conducted to compare the histology of gonads of wild-caught and captive *P. vannamei* of known ages [55]. Captive individuals could develop mature gonads at 11 months after post-larvae 15 (ovaries contained 50% mature oocytes; testes contained 80% mature sperm cells). The result of the study showed that 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. However, the authors cannot conclude that escapees can establish a feral population because the study might have under-sampled sexually mature individuals due to inappropriate sampling sites and timing. This issue remains important for further investigation. A monitoring program in offshore areas may provide opportunities for us to obtain sexually mature individuals. Likewise, Panutrakul et al. [44] found no evidence that the shrimp present in the wild could reach maturation in the Bangpakong River although gonadal development has been observed. Moreover, Wakida-Kusunoki et al. [35] argued that it was not possible to find evidence of *P. vannamei* becoming established in the zone of the Mexican coast of the Gulf of Mexico. The low frequency of *P. vannamei* encounters in the monitoring program of artisanal shrimp fishing in lagoon system and the negative presence of the shrimp in surveys of the commercial shrimp catches of coastal waters near to the mouth of this lagoon indicate the absence of an established population. They suggested further sampling and monitoring are required to find evidence that confirms the establishment of a population of the shrimp in the Southern Gulf of Mexico. According to Panutrakul et al. [44], natural reproduction would require released adults and a high probability that the mature adults could find mates. In the Philippines, the population of *P. vannamei* in the wild therefore already exists, although it is still uncertain if this population is now breeding [29] until this time.

5. Can *P. vannamei* potentially compete with native shrimp species?

Studies have shown that there is a potential risk of a negative impact of the introduced Pacific whiteleg shrimp *P. vannamei* on native species and the invaded ecosystems [21, 30, 44]. An alien species like *P. vannamei* could potentially interact with local species through food competition, either by exploitative or interference competition [21].

Recently, Chavanich et al. [56] conducted a laboratory assessment of feeding-behavior interactions between the introduced *P. vannamei* and five native shrimps plus a crab species in Thailand. Results showed that the shrimp was nonselective with respect to the palatability of the five native shrimps as food. The shrimp was behaviorally dominant when competing for food one-on-one with the native shrimp species. According to Gamboa-Delgado et al. [57], the shrimp is an opportunistic feeder that can adapt well to changes in diet composition. Though laboratory studies could not represent the feeding interactions under field conditions, the non-native shrimp could become a serious threat to native shrimps when the frequency of escapes is increasing and when they begin to reproduce successfully. One of the key factors influencing the success of invading species is propagule pressure or total quantity [58, 59]. Increasing the propagule pressure may enhance the foundation of an invasive population [58]. In Bangpakong estuary, increased frequency of encountering the shrimp is reflecting an increase in propagule pressure because the frequency of escapes is increasing [30]. However, Chavanich et al. [56] suggested more studies are needed to provide insights into the interactions between the introduced white shrimp and native shrimp species and into the ecosystem-wide consequences of this introduction.

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

Diseases are worldwide top issues and challenges in shrimp aquaculture based on the survey of global aquaculture alliance from 2016 to 2017 [60]. Modern shrimp farming is, in a way, shaped by viral disease outbreaks in the nineties and early 2000s [61]. On the other hand, Itsathitphaisarn et al. [62] reiterated that viral pathogens pose a primary threat to global shrimp aquaculture. According to Lightner and Redman [63], there are about 20 viral pathogens that can cause serious epizootics in penaeid shrimp. In the Philippines, major viral pathogens affecting the shrimp aquaculture include white spot disorder infection (WSSV), monodon baculovirus (MBV), irresistible hypodermal and hematopoietic rot infection (IHHNV), hepatopancreatic parvovirus (HPV), yellow head infection (YHV), and Taura disorder infection (TSV) [61].

A disease caused by TSV was first described from Ecuador in the early 1990s. Lightner [64] and Lightner [65] reported that the disease outbreaks caused catastrophic losses with cumulative mortality rates of 60 to >90% in pond-cultured shrimp. The principal host species for TSV are the *P. vannamei* and the *P. stylirostris*, and it has been documented in all life stages (i.e., post-larvae, juvenile, adults) of *P. vannamei* except in eggs, zygote, and larvae [66]. TSV is a particularly virulent pathogen of *P. vannamei*, and it can infect several other shrimp species including *P. monodon*, *P. aztecus*, *P. duorarum*, *Litopenaeus setiferus*, *L. stylirostris*, *Marsupenaeus jaiponicus*, *Macrobrachium rosenbergii*, *Metapenaeus ensis*, *Fenneropenaeus chinensis*, and *L. schmitti* [61].

According to Wertheim et al. [67], TSV is now widely distributed in the shrimp-farming regions of the Americas, Southeast Asia, and the Middle East. Additionally, evidence showed that TSV is present in natural populations of *P. vannamei* in Central America such as Mexico and Ecuador and may be elsewhere [66, 68]. The international trade of live shrimp resulted in a rapid spread of TSV in the Americas and Asia [69]. TSV was introduced to Asia in 1998 by careless importation of shrimp stocks for aquaculture but has not been reported to cause problems with local crustacean species [70]. Recently, Thitamadee et al. [71] reported TSV has become innocuous due to the widespread use of highly tolerant specific-pathogen-free (SPF) stocks of *P. vannamei* that dominate production.

In the Philippines, there was no documentation on the introduction of *P. vannamei* from Panama into Iloilo in the 1970s and from Hawaii in 1990, and it was not known whether the exotic species introduced any new pathogens [18]. As of 2015, there was no documented report regarding TSV presence in the Philippines [61] and have yet to be detected as stated in the NACA, OIE, and FAO [72] quarterly animal disease report of 2018. However, this will not justify that TSV is not present in the Philippines because there was no study conducted on the detection of the viral disease since the introduction of *P. vannamei* until the importation ban was lifted in 2007 up to 2018. Rosario and Lopez [36] reported that even with the strict implementation of the BFAR formulated FAO 207 series of 2001 which further strengthened FAO 189 series of 1993 which among others prohibit the importation of exotic shrimps and strict surveillance in airports, traders were finding other ways in bringing the illegal shrimp inside the Philippines without passing through the airports. Shrimp Importation, Monitoring, and Surveillance (SIMS) team spearheaded six major confiscations in late 2002 up to 2003 and reported around 700 have illegal *P. vannamei* farms operating in Luzon. Moreover, despite all the efforts of the BFAR, the culture industry for the shrimp in the Philippines has grown and may produce as much as 5000 metric tons in 2003 [29]. In fact, Philippines was one of the main producer countries of *P. vannamei* based on FAO fishery statistics in 2006 [73]. According to de la Peña [74], there is always the possibility of contamination with TSV if the illegal shipments of the shrimp remain uncontrolled, and this proves recently as the study of Vergel et al. [75] reported for the first time the presence of TSV in *P. vannamei* in the Philippines using morphological and molecular techniques. BLASTn search results showed that the TSV sequences have very high sequence similarity at 86–100% with TSV viral isolates from other countries (Taiwan, Thailand, Venezuela, the USA, Colombia, and Belize). The detected prevalence rates of the study comprise a small sample population with limited areas in the Philippines, namely, Bulacan (33%), Batangas (47%), Bohol (7%), and Cebu (13%). The authors suggested further testing in other sites in the country and implementation of mitigation methods and policies to prevent further spread of the viral disease. Likewise, detection of TSV in the wild is also important to be conducted. In the study of Barnette et al. [76] using PCR and immunological analyses, results suggested that TSV has already spread into the Bangpakong River and the Gulf of Thailand. The viral disease appeared to be more widespread in dry seasons than wet seasons. The presence of TSV has been detected in *P. monodon* adults; local shrimp species of the Bangpakong River such as *P. monodon*, *P. semisulcatus*, *P. merguiensis*, *M. brevicornis*, *M. affinis*, *M. tenuipes*, *Parapenopsis hungerfordi*, and *M. rosenbergii*; two other species belonging to the Family Caridea; and wild-caught *P. vannamei* including green mussel *Perna viridis*, blue swimming crab *Portunus pelagicus*, and Asian sea bass *Lates calcarifer*. TSV was detected in *L. setiferus* and *Farfantepenaeus aztecus* in Laguna Madre [77] and *L. schmitti* in Maracaibo lagoon, Venezuela [78].

7. Social impacts

With or without valid arguments, aquaculture has been accused to be the cause of many problems such as environmental, economic, inclusively esthetic, and social impacts [79]. In Vietnam, social impacts associated with shrimp farming include the increase of poverty and landlessness, food insecurity, and impacts on health and education [80, 81]. While there is no recent information regarding the social impacts of shrimp farming particularly the use of alien species such as the *P. vannamei* in the Philippines, Primavera [82] reported that the social costs of intensive prawn farming include the reduction of domestic and agricultural water supplies, decline in quantity of food fish, marginalization of coastal fishermen, displacement of labor, and credit monopoly by big businessmen. The capital-intensive nature of high-density shrimp culture has favored the entry of multinational corporate investors or the national elite. They can provide the necessary capital; have easier access to permits, credits, and subsidies; and can absorb financial risks which are disadvantaged to local communities in coastal areas and small farmers [83]. One main issue in the recent expansion of shrimp culture is social conflicts with other resource users; however, the shrimp culture industry employs thousands of rural people, and it would be far worse off without it [73].

8. Conclusion and recommendation

The presence of Pacific whiteleg shrimp *P. vannamei* in the Philippines has already reached more than five decades, and this raises ecological and social concern. This review paper aimed to evaluate the ecological and social impacts of aquacultural introduction to the Philippines waters of Pacific whiteleg shrimp *P. vannamei*. Several questions were answered and discussed based on literature, scientific details, reflections on personal experience, and their relevance to aquaculture of the *P. vannamei* in the Philippines to evaluate the ecological impacts, while social impacts were discussed based on literature. Findings revealed the escapes of *P. vannamei* from aquaculture production facilities of several countries into non-native waters including the Philippines. The presence of *P. vannamei* in the wild was due to the intentional release in attempts to escape detection during the implementation of a ban on the importation of all live shrimp in the Philippines and also possibly due to escapes from intensive and expanding production cycles as well as natural calamities such as floods. Consequently, the ability of *P. vannamei* escapees to survive the natural environmental conditions due to their tolerance to a wide range of salinity and pH could lead to ecological concerns such as resource competition, reproduction, and spread of disease in the wild. Studies reported that *P. vannamei* could potentially interact with local species through food competition, either by exploitative or interference competition. While there is no evidence that *P. vannamei* can establish population outside of its natural geographic range, natural reproduction of escapees is still possible once released mature adults could find mates in the wild. Thus, if the frequency of escapes is increasing and when they begin to reproduce successfully, the non-native shrimp *P. vannamei* could become a serious threat to native shrimps. The most problematic consequence of *P. vannamei* farming is the spread of the alien pathogen, Taura syndrome virus (TSV), which is rapidly spread due to international trade and now widely distributed in the shrimp-farming regions of the Americas, Southeast Asia, and the Middle East. The proliferation of TSV in *P. vannamei* farming has resulted in catastrophic losses and transmission of the disease in the wild wherein crustaceans (other shrimps and crabs) including fish (Asian sea bass) can be infected. In the Philippines, TSV presence in farmed *P. vannamei* was reported for the first time since its introduction in the 1970s. On the other hand, there is no specific information on the social impacts of *P. vannamei* farming; however, the recent expansion of shrimp culture has resulted in social conflicts with other resource users.

This review shows the negative implications on the aquacultural introduction of Pacific whiteleg shrimp *P. vannamei* in the Philippines both ecological and social aspects, and this heightens important management issues. Below are recommendations to ensure sustainable farming of *P. vannamei* in the Philippines:

1. Strict implementation of the guidelines for the importation and culture of the shrimp based on Fisheries Administrative Order No. 225, Series of 2007. Illegal *P. vannamei* farming must be prohibited.

2. Strengthen the screening requirements for the importation of all the shrimp stages, accreditation of hatchery, and grow-out facilities to eliminate the spread of TSV and escapees into the natural ecosystem. Monoculture of the shrimp must be one of the critical requirements for grow-out farm accreditation. Accredited hatcheries must only allow selling seedlings to accredited grow-out farm operators and for research purposes to eliminate illegal farming.

3. A collaborative program must be implemented on the nationwide detection and prevalence of TSV by concerned agencies such as DA-BFAR, DOST-PCAARRD, SEAFDEC/AQD, and SCU's in cooperation with private shrimp growers.

4. Establishment of a monitoring program for the presence of the shrimp and TSV in the wild to detect the geographic spread of escapees and the disease as well as their impacts.

5. Conduct social impacts of expanding *P. vannamei* farming.

6. Continuous support of the government for research to create sustainable aquaculture production of the shrimp.

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