WILDLANKA Vol.9, No.1, pp. 149 - 170, 2021.

REVIEW ON IMPACTS OF *Litopenaeus vannamei* ON AQUACULTURE

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ABSTRACT : Aquaculture is the aquatic equivalent of agriculture or farming on land. According to the FAO, aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Currently worldwide more than 220 species of finfish and shell fish are farmed in aquaculture. From the cultured species marine shrimps dominates the crustacean aquaculture where Farming locally available shrimp species from wild captured post larvae was the most common method followed. With the development of modern aquaculture techniques shrimp farming subjected to a vast array of changes and introduction developed species across the world was evident. As a result, shrimp species native to the West, *L. vannamei* was introduced to many countries despite its natural range. With the growth of huge aquaculture trend towards this introduced species around the world it is a timely need to assess the impact of this species in global scale. This paper documents the overall impact of *L. vannamei* on aquaculture in biological, environmental and social aspects, assessed using peer reviewed and credible sources addressing the total pay-off it has resulted with the massive movement as "most widely cultured alien crustacean in the world".

KEY WORDS: Aquaculture, Diseases, *Litopenaeus vannamei*, Pathogen

INTRODUCTION

The current global population of 7.7 billion people is estimated to grow to 9.7 billion in 2050 (World Population Prospects, 2019). Food industries look towards Aquaculture for its consistent and reliable contributions to meet the increasing protein demands to feed the growing population (Gentry *et al.*, 2017). Considered as one the of the rapidly developing primary production sector around the world, Aquaculture is an agroecosystem that thrives in coastal, marine and estuarine seascapes (Alleway, 2019). The industry largely involves the farming of aquatic organisms with interventions in the rearing process to enhance the production for commercial, public and recreational purposes. The sector contributes to 50 percent of the world's fish food production (Food and Agriculture Organization, 2020). Since 2000, the global aquaculture production has grown two fold from 41.7 million tonnes to 90.4 million tonnes in 2012 with a growth at an annual average rate of 6.7% (Tacon and Metian, 2015). In 2018, the global industry reached a record high of 114.5 million tonnes in live weight with a farmgate sale value of USD 263.6 billion (FAO, 2020). Complete or partial artificial structures are built adjacent to the sea for Coastal Aquaculture. Modern or traditional coastal ponds for the practice are found around the globe with many found in South, Southeast and East Asia and Latin America. Such developing countries largely rear crustaceans, finfish and molluscs. In 2018, 9.4 million tonnes of crustaceans were reared globally with a value of USD 69.3 billion (FAO, 2020). In the recent years, shrimps are considered as one of the most valuable globally traded crustacean with a contribution of more than 4.5 billion tonnes to its global consumption. *Litopenaeus vannamei* (*L. vannamei*) is the dominant cultivated species with China, India, Thailand, Mexico and Vietnam being its largest producers (Hatje *et al.*, 2016; Landsman *et al.*, 2019). Prior to its emergence in 2000, the primary cultivated shrimp species in Asia was the *Penaeus monodon* (*P. monodon*). As a result of its ability to avoid certain diseases, introduction to specific pathogen free and domestication, *L. vannamei* replaced *P. monodon* as the dominant cultivated species (Thitamadee *et al.*, 2016). *L. vannamei* is native to the eastern Pacific coast of Central and South America from Tumbes, Peru in the south to Mexico in the north. The first spawning of this species was done in Florida (in 1973) from nauplii spawned and shipped from a wild-caught mated female from Panama. Following good pond results and the discovery of unilateral ablation to promote maturation in Panama in 1976, commercial culture of *L. vannamei* began in South and Central America. This species has been introduced widely around the world since the 1970s. Since it has become the principle cultured shrimp species in Asia, that region has seen a phenomenal increase in the production of *L. vannamei*. However, due to fears over importation of exotic diseases, many Asian countries have been reluctant to promote farming of *L. vannamei*, so that its culture remains officially confined to experimental testing only in Cambodia, India, Malaysia, Myanmar and the Philippines.

L. vannamei is known to carry a range of diseases (including viral diseases) that can affect both this species and the native crustacean species in countries where it has been introduced. Obviously, this can have negative consequences on its culture and the culture of the indigenous species and possibly on wild stocks. It is suspected that diseases including Taura syndrome virus, infectious myonecrosis virus and necrotizing hepatopancreatitis have been brought into Asia from Latin America with introductions of white leg shrimp. Although some countries such as Thailand and Indonesia both freely permit commercial culture of *L. vannamei*; but have official restrictions. So that only Specific Pathogen Free (SPF)/ Specific Pathogen Resistant (SPR) broodstock may be imported. Similarly, most Latin American countries have strict quarantine laws or bans to prevent importation of exotic pathogens with new stocks. The species is naturally distributed in the Eastern Pacific Ocean from off Northern Mexico to off Northern Peru. The white legged shrimp gained its popularity after its introduction to China and due to its tolerance to a range of temperatures and salinity ranging from brackish water of 1-2ppt to hypersaline water of 40ppt (Zhong *et al.*, 2015). *L. vannamei* or otherwise referred to as Mexican white shrimp or white legged shrimped belongs to the order or group of crustaceans of Decapoda. Defining features of the shrimps from the rest of the decapods include the similar size of the front-most section of the abdomen to the rest of the sections, five pairs of abdominal appendages adapted for swimming (Bridson, 2010). The *L. vannamei* species are greyish-white in colour and are characterized as omnivorous scavengers and are considered to be less aggressive and carnivorous in comparison to *P. monodon*. The wild species prefer clayey loam soil where the females can grow up to 120g and the males up to 80g in size. However, under controlled culture conditions, the shrimps are bred until 20g which is attained within 100-120 days depending on the stocking density. The optimal temperature for their growth is between 30 and 34°C with a dissolved oxygen level above 4.5ppm. The shrimps are characterized with a tolerance level between 0 to 50ppt for salinity level and a pH range between 7 to 9 with an optimal growth at pH 8.0 (Jithendran, 2012). In comparison to P. monodon, *L. vannamei* shrimps require low protein food and retain the potential to grow at a faster rate in intensive culture conditions and in high density pond systems in Asian Earthen ponds. The species are amenable to culture in stocking densities of 150/m2 in pond cultures and 400/m^2 in controlled recirculated tank cultures (Briggs *et al*., 2004).

Mainland China and Taiwan

The first record of importing *L. vannamei* in China was in 1988 from the USA as an experimental project and on a commercial scale from 1996. Same time SPF *L. vannamei* broodstock was first shipped to Taiwan in 1996 and by 1997 distribution of PL from hatchery across Taiwan was performed (Wyban, 2003 and 2017). China and Taiwan hold the record of the highest establishment of *L. vannamei* than any other country. First, *L. vannamei* culture was carried out in brackish water and due to serious virus outbreaks, moving culture systems to freshwater and has started culturing with desalinized shrimp larvae in 2001. freshwater culturing was rapidly popularized due to the success experienced than in brackish water systems (Sulit *et al*., 2005). From all cultured shrimp species namely Penaeus chinensis, *P. monodon*, *Penaeus japonicus*, *Macrobrachium rosenbergii* and *Procambarus clarkii*, *L. vannamei* accounts for more than 50.61% in 2016 from the total production and dominates the industry. The culture of *L. vannamei* was observed in more than 28 provinces in China and the top leading provinces are Guangdong, Jiangsu, Hubei, Zhejiang and Guangxi provinces. Out of total production from China, up to 36.8% is contributed from Guangdong province making it number one followed by 12.62 % from Guangxi province (Che *et al*., 2018). Due to unregulated imports and poor law enforcement, China was experiencing serious disease outbreaks since the start of the industry resulting in a major outbreak in 2001. Viral diseases like TSV, LOVV, REO III and BP were observed most probably transferred from infected broodstock (Briggs et al., 2004).

India

With the introduction of *L. vannamei*, the shrimp industry of India has been subjected to huge change. *L. vannamei* was first introduced to India in the year 2001 from Taiwan (Briggs *et al*., 2004). After risk assessment and proper legal permission, India initiated its commercial *L.vannamei* production in 2009 and good production outcome was experienced which accounted for 54% from total shrimp production in 2012-2013 (Kumaran *et al*., 2012; Mahesh *et al*., 2013). The dominance of *L. vannamei* over previously cultured species such as *P. monodon* and *Macrobrachium rosenbergii* is clearly seen with the huge market trend created favoring vannamei culturing. With the popularity, Indian shrimp industry boosted up to 83% and India became the second-largest shrimp producer in the world. Andhra Pradesh, Orissa, West Bengal, Tamil Nadu, Karnataka, Kerala, Maharashtra, Gujarat and Goa are the main areas currently under culture (Salunke *et al.*, 2020). But the same situation is experienced like in previous monodon culture such as sustainability issues causing direct threat towards farmers, mainly due to reports of disease outbreaks. Also, factors such as lack of quality seed stocks, operations of unregistered hatcheries, high feed costs with the use of false drugs, chemicals and usage of banned antibiotics and probiotics are major concerns. Furthermore, market problems including huge amounts of container rejections, traceability problems and market value changes have posed serious threats to *L. vannamei* culture in India (Venkatrayulu, 2019).

Indonesia

The first introductions of *L. vannamei* broodstock and PL were performed in East Jawa and Bali provinces, in late 1999s from Taiwan. From experimental culture, successful production was reported with acceptable levels and this leads many *P. monodon* farmers to switch to commercial culturing of *L. vannamei* which eventually increased the contribution of shrimp to national production up to 41.2% in 2003. From the total production of shrimp more than 75% accounts from *L. vannamei* where semi-intensive culture systems and intensive systems are dominated by *L. vannamei* (Liao and Chien, 2011; Sulit *et al.*, 2005).

The main provinces engaged in commercial *L. vannamei* culture are Bali, Lam- pung, West Java, Central Java, South Sumatera, North Sumatera, Bangka, Belitung, Riau, West Ka-limantan, East Kaliman- tan and West Nusateng-gara and Bengkulu. Indonesia was holding the 4th place in of *L. vannamei* production in 2017, while ranked 2nd place until it was overtaken by China and Vietnam. The occurrence of viral diseases such as TSV and WSSV was observed across many districts spreading mainly from the transportation of infected postlarvae (Budhiman *et al*., 2005).

Vietnam

L. vannamei was first imported to Bac Lieu province in 2001 from Taiwan by private companies with the licenses issued by the Vietnam Ministry of Fisheries. The major cultured shrimp species is Penaeus monodon while *L. vannamei* ranks in second place and Vietnam is considered as one of the top five *L. vannamei* producing countries. Continuous growing in P. monodon is experienced unlike in most Southeast Asian countries. Since *L. vannamei* introductions the culture was kept under the governments control for 7 years expecting rapid action in any disease outbreak and due to lack of experience and knowledge regarding the species (Liao and Chien, 2011). Culture is mainly practiced in the Mekong Delta area and provinces like Ca Mau, Bac Lieu and Soc Trang dominate the culture accounting for more than 78% of the total production. Since 2012 80% of shrimp culture systems are affected by Early Mortality Syndrome and reports indicated that rice farmers in Mekong area have shifted away due to increased salinity conditions that occurred due to shrimp farm activities. With the increase of diseases, the use of more and more antibiotics, injecting Agar to increase weight and the use of other unwanted chemicals has caused concerns in export markets. Traceability problems and invalid sources of origin are also considered as major concerns in the Vietnam shrimp industry (Nguyen Tan Sy, 2017).

Thailand

The first introduction of *L. vannamei* was in 1999 which is considered to be an illegal importation and it continued till 2002 due to the success experienced with the species. Since 2002 the government involved in the regulation process and initiated official importations.TSV and IHHNV outbreaks were experienced with the initially imported stocks and with that concern import regulation imposed by the government ended in 2003. It is evident that with the import regulation process smuggling of non-certified *L. vannamei* from China and Taiwan intensified the disease outbreak. Hence after that due to the pressure from market demands and lack of quality broodstock department of fisheries again commenced the importations with specific requirements mentioned by the department. Biosecurity, SPF or SPR certificates and other health certificates were major requirements listed. The *L. vannamei* production increased up to 96% of total shrimp production in 2018 and 30% in total aquaculture production, until 2012 Thailand was considered as one of the top *L. vannamei* producers in the world but now hold the position of sixth due to recent serious disease outbreaks (FAO, 2018; DOF, 2020). On the other hand, this massive introduction of *L. vannamei* has resulted species to be found in natural environments (Senanan *et al*., 2007; Liao and Chien, 2011).

Philippines

In 1978 first introductions of *L. vannamei* were made and due to unsuccess experienced the harvest was accounted for local consumption. With the rapid spread of shrimp diseases in Asia, The Bureau of Fisheries and Aquatic Resources introduced regulations on shrimp and prawn exportations. Since then though the pressure from the private sector to lift the ban on exotic shrimp importations and allow commercial culture was immense but was not permitted by the government. Due to the serious disease outbreaks in *P. monodon*, smuggling of *L. vannamei* to the country, neglecting existing laws was highly increased. With this trend again government imposed more serious laws and regulations on importing exotic shrimp species. Intentional release and damages to shrimp farms by strong typhoons have resulted in the release of *L. vannamei* to natural water bodies. With all the concerns existing in the country, in 2004 the government in collaboration with private companies initiated the experimental culture of SPF and SPR *L. vannamei* in Bonuan Binloc and Dagupan. Still, *P. monodon* dominates the shrimp production as the main cultured shrimp species due to the cost of production and price variations in *L. vannamei* culture (Briggs *et al.*, 2004; Rosario *et al.*, 2005).

Immune System

Use of *L. vannamei* shrimps enable the culturist to avenues of genetic selection, development of SPF and Specific Pathogen Resistant SPR stocks. Nonetheless, the species remains highly susceptible to pathogens (Jithendran, 2012). In order to defend against the pathogens, shrimps rely on their innate, non-specific immune system that includes the cellular responses of phagocytosis, encapsulation, apoptosis and nodule formation and humoral immune responses of lectins, antimicrobial peptides and clotting cascade. Both responses are carried out by haemocytes that are present in open circulatory system or hemolymph of shrimps (Musthaq *et al*., 2014). Given the shrimps' non-specific immune system and their ability to act as carriers, diseases and subsequent outbreaks have been a constant threat to the shrimp farming industry in the aspects of the production and economics (Bridson, 2010). Diseases are classified as infectious or noninfectious. Etiological agents that causes infectious diseases in shrimps ranges from virus, bacteria, fungi to adverse environments, nutritional deficiencies and algal toxins. The industry faces significant economic losses due to a range of diseases. India suffered an estimated economic loss of Rs.1000 crores between 2006-2008 (V enkateswarlu and V enkatrayulu, 2019). Environmental stressors and overstocking are attributes to disease outbreaks and national and international transfer of brood stock, seed and larvae contributes to widespread of pathogens around the globe (Ahamed *et al*., 2017). Bacterial and viral diseases have adverse effects on the culture species with a global production loss of approximately US$15 billion between 1997 and 2012 (Flegel, 2012).Specifically, viral diseases including White spot syndrome virus (WSSV), Taura syndrome (TSV) and Yellow head virus (YHV)have caused significant economic losses, approximately USD 6 billion in 2016 (Rizan *et al*., 2018,). In addition, the disposal of the dead organisms contributes further to the economic loss (López-Téllez, 2018).

In the late 1980s, the U. S Shrimp Farming Program was set to establish SPF shrimps in order to tackle the constant disease outbreaks. Shrimps are classified as SPF if they were bred in a SPF facility that are certifiably free of pathogens that can be reliably diagnosed and physically eliminated from a facility (Wyban,2016). The shrimps are repeatedly examined and are characterized as pathogen free with the use of intensive surveillance protocols, and originate from broodstock characterized with rigid and controlled founder population development protocols (Briggs, 2004). The pathogens include WSSV, TSV, YHV and Infectious Haematopoietic Necrosis Virus (IHHNV). Furthermore, bio security protocols prevent disease contamination of the SPF to develop High Health post-larvae (Wyban, 2016). In definition, the SPF stock are free of a given listed pathogens, however, the possibilities that the shrimps are genetically resistant, infected with a pathogen that is not included in the SPF list or with an unknown pathogen remains. The TSV outbreaks in the Brazil and Colombia were a result of the SPF shrimp shipped from Hawaii. Given that, at that time, TSV was not known as a pathogen it went unchecked in SPF protocols. Emergence of new diseases from mutations of previously non- pathogenic organisms and stocking of SPF shrimps in facilities with heavy viral loads to which the shrimps are not more resistant than non-SPF shrimps can lead to mortality for the shrimps, are possibilities that remains with SPF stock (Briggs, 2004). Given their high susceptible to pathogens, survival, growth and stocking densities of the shrimps are primary concerns in the industry. *L. vannamei* shrimps are stocked at densities ranging from 150 to 600 shrimps m^{-3}, postlarvae are reared in densities as high as 1556 shrimps m^{-3} and shrimps are transported in maximum densities of 5-40 shrimp L^{-1}. Throughout the decades, research has indicated that such high densities result in pathogen outbreaks, poor water quality and negative production, growth and survival. Shrimps reared at densities higher than 20 and 40 shrimp L^{-1} had higher mortality rates and were lower in resistance against WSSV and *V. alginolyticus* - a marine bacterium. Shrimps reared at densities of 10, 20, 30 and 40 shrimp L^{-1} experienced lower immune parameters of total haemocyte count, hyaline and granular cells, and phenoloxidase and lysozyme activities. Such reduced immune parameters subsequently lead to decreased resistance to pathogens (Lin *et al*., 2015). High stocking densities increases cumulative mortality- the densities increase stress levels in organisms which has a strong influence on disease outbreaks and transmission of diseases (Raja *et al*., 2015).

Environmental Stressors

Non-biological factors including physical and chemical properties of the surrounding water such as temperature and pH are known to affect the non-adaptive immune system of shrimps. Prolonged and intense environmental factors negatively affect the immune system with each environmental stressor or combination of stressors bringing about different effects (Chen *et al*., 2019). Exposure to ammonia-nitrogen disrupts the composition of intestinal microorganisms and damages the intestinal mucosa. The aforementioned are essential for the efficacy of the intestinal wall that functions as the first line of defense to the invasion of foreign matters. Therefore, damages to the intestinal microorganisms and mucosa hinders the immune function (Duan *et al*., 2018). Significant damages in plasma RB activity and hemocyte DNA, decrease in plasma total hemocytes count and protein content were observed when *L. vannamei* were subjected to cold stress of 12°C (Qiu *et al*., 2011). Furthermore,the humoral immune signaling pathways in shrimps such as the TLR/IMD- kB signaling pathway is significantly affected by ammonia-nitrogen exposure (Guo *et al*., 2013). Frequent outbreaks brought about by a range of pathogens include causes major production and economic losses with subsequent impacts on employment, social welfare and international market. More than 20 viruses have been reported as pathogenic to shrimps.

White Spot Syndrome

White Spot Syndrome or WSSV is a viral disease known to cause significant economic loss with a mortality ranging from 80-100% within three to ten days. Shrimps species reared both in marine and brackish water are susceptible to WSSV. Shrimps of all ages and size in grow out culture are susceptible to the adverse pathogen with the highest mortality rate reported after 1-2 months after stocking (Trang *et al*., 2019). Bright milky colour white spots are the defining symptom of the disease. The virus is a rod-shaped enveloped double stranded DNA virus that first appeared in 1992 in the farms of Northern Taiwan and was later isolated from shrimps in Japan in 1993. Since then, the virus spread to almost all shrimp cultures around the globe and is considered to bring about significant annual economic loss (Mustaq *et al*., 2014). The virus is able to survive in free water for seven days and the direct use of sea or creek water introduces the virus into the system (Jitendran, 2012). Pumping of water with a lack of filtration and disinfection, cross contamination and lack of biosecurity are considered are factors that causes the disease's outbreaks (Venkateswarlu and Venkatrayulu, 2019). WSSV contaminated postlarvae were introduced to Mexico when diseases such as Baculovirus penaei and Infectious hypodermal and hemotopoietic necrosis virus were endemic. As a result of the outbreak in 1999, the production declined throughout that year to 2002 and 2012. The reappearance of the virus in 2005, 2010 and 2012 brought about significant economic loss of 100 million dollars in 2005 in the farms in Sonora, Sinaloa and Nayari (Esparza-Leal *et al*., 2010). A decade later in 2016, the industry faced an economic loss of USD 6 billion (Rizan *et al*., 2018). The recurrence of the pathogen characterizes itself as a constant threat to the industry. Challenges are faced for the eradication of the pathogen for the virus has more than 100 hosts and affects crustaceans that live in marine, fresh and brackish water. In addition, the virus affects microalgae, rotifers, bivalves and ploychaetes that act as mechanical vectors as they are able to accumulate heavy viral loads (López-Téllez, *et al*., 2019).

The presence of the virus as threat to shrimp farms in Asia is due to insignificant control measures. Current practices rely on preventative measures such as the use of domesticated and genetically selected shrimps and SPF stocks (Thitamadee *et al*., 2016), management practices, specialized formulated diets to enhance the immune system and modifications in the environmental rearing conditions. However, the aforementioned practices are not considered as feasible and cost effective (Trang *et al*., 2019) and the development of vaccinations faces challenges in the improvement of the protection rate and long-term efficacy (Mustaq *et al.*, 2014). Environmental stress that affects the susceptibility of WSSV in shrimps includes exposure to ammonia nitrogen, osmotic pressure and salinity levels. Increase in levels of osmotic pressure (35g/l to 50g/L, 35g/L, or 20g/L) and changes in salinity increased the susceptibility to the disease. Substantial changes in ammonia-nitrogen level, heterotrophic bacteria count and oxygen concentration following a tropic storm are factors that contributes to a WSSV outbreak (Zhang *et al*., 2016).

Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV)

Infectious hypodermal and hematopoietic necrosis virus or IHHNV is a small icosahedral nonenveloped virus with a single stranded linear DNA that was first detected in juvenile *P. stylirostris* from Hawaii in 1981. Due to the transfer of infected shrimps, the virus has been introduced in various stages of life in penaeids in South and East Asia, Oceania and America. The virus is known to infect *P. chinensis*, *P. monodon* and *L. vannamei* with significant negative consequences including a mortality up to 90%. In *L. vannamei* shrimps, IHHNV is associated with runt deformity syndrome that is characterized with stunted growth rate, specified by high levels of consumption and cuticular deformities that affects the thoracic and abdominal areas of the exoskeleton, rostrum and antennae (Ahamed *et al*., 2017).

IHHNV and WSSV are known to bring about significant damages and consequences to the shrimp industry and it can only be assumed that the concurrence of both would heighten the losses and be detrimental to the industry. With the use of transmission electron microscopic or TEM, contemporary research in India observed both IHHNV and WSSV viral particles in gill tissues that suggest a co-infection. IHHNV remained in latent form in the host however, the changes in size, shape and envelope formation suggests WSSV in different stages of morphogenesis. The maturation of the virus implies its command and establishment of the host cell (Dewangan, *et al.*, 2017). In experimental challenges, mortality was reached on the 4th day in shrimps infected with WSSV and IHHNV (Bonnichon *et al.*, 2006). A mutual competition to bind to specific receptors in the cell membrane was observed from both viruses. Reported studies observe the interference by IHHNV on WSSV. This is because WSSV is characterized with high potent toxicity and shrimps die before the interference by IHHNV. Furthermore, WSSV possess stronger binding ability in comparison to the other virus and is therefore able to bring about inhibitory effects on IHHNV (Yan *et al.*, 2016). In 2002, an outbreak of a muscle diseases in farmed shrimps in northeast Brazil brought about devastating consequences. Within a year, the virus spread to the neighbouring regions and caused an economic loss of worth US$20 million. Infectious myonecrosis virus or IMNV was identified as the causative agent. The non-enveloped icosahedral virus with double-stranded RNA genome causes morbidity and mortality of shrimps at any stages with juvenile shrimps being the most susceptible to high mortalities. The acute and chronic onset of the disease is brought about by environmental stressors. With the use of reverse transcription polymerase chain reaction or PCR, detection of co-infection by both IMNV and IHHNV at a high prevalence was reported in shrimps reared in the farms in Northeast Brazil. Assessments by quantitative real time PCR or qPCR revealed reciprocal values that suggests a competition between the viruses for the host (Teixeria-Lopes *et al.*, 2011).

Acute Hepatopancreatic Necrosis Disease/ Early Mortality Syndrome

In 2013, shrimps in farms of the northwest Mexico suffered unusual deaths within the first days of stocking. Similar characteristics and incidents were then observed in Sonora and Sinaloa states that brought about an economic loss of 2.5million pesos. Preliminary assessment revealed anorexia, discoloration of hepatopancreas (HP) and lethargy as clinical signs. Microbial analysis revealed a heavy load of Vibrio - bacteria that causes necrotic lesions in the tissues of the infected shrimps. Infected shrimps are characterized by empty stomachs, slow growth and their sluggish swimming followed by mortality within 7 to 35 days after stocking. (Songsanginda and Polchana, 2016). Like any other diseases, acute hepatopancreatic necrosis disease otherwise referred to as early mortality syndrome caused major production and economic losses with subsequent impacts on employment, social welfare and international market. The disease is a result of the Vibrio parahaemolyticus that colonizes in the stomach and produces soluble toxins that causes sloughing (Shen *et al*., 2017). As a result of an outbreak of the disease, production of shrimps in Thailand dropped from 600,000 metric tons in 2011 to less than 200,000 in the next three years. From 2012 to 2015, the outbreak of the disease was responsible for a cumulative production loss of ca. 768,081 MT (Songsanginda and Polchana, 2016). Initial, acute and terminal are identified as phases of the disease. During the initial stage,hemocytic response as a first line of defense was not observed suggesting the bacterial attack is quicker than the activation of the immune system (Soto-Rodriguez *et al.*, 2014). Characterized with a toxin-mediated etiology, the pathology of the disease is limited to the HP, however during the acute phase, significant bacterial involvement is not observed in HP. In the early onset of the disease, due to the loss of pigments, the colour of HP is observed as pale to white and atrophy of the organ reduces its size to more than 50%. In the late and terminal stages of the disease, black spots or streaks are observed in the HP due to melanin deposition from hemocyte activity (Trans *et al.*, 2013).

Hepatopancreatic Microsporidiosis (HPM)

Caused by Enterocytozoon hepatopenaei (EHP), the disease was first reported from growth retarded *P. monodon* reared in Thailand in 2004. In 1989, a morphologically similar and unknown microsporidian was reported in the HP of *P. monodon* reared in Malaysia (Anderson *et al.*, 1989) and in *P. japonicus* from Australia (Hudson *et al.*, 2001). The microsporidian is known to affect both *L. vannmei* and *P. monodon* and is associated with severe growth retardation (Tangprasittipap *et al.*, 2012). EHP is reported to show no gross signs of the disease and only affects the tubule epithelial of the shrimp HP. Reports suggest the direct transmission of the microsporidian by cohabitation and cannibalism, making challenges in control measurements (Thitamadee *et al.*, 2016). Infected shrimps are able to vertically transmit the spores to their offsprings and infected postlarvae could horizontally transmit the spores to the rearing water subsequently infecting other stocks (Songsanginda and Polchana, 2016). Research further suggest other penaeid shrimps and/or crustaceans or species in marine or brackish water are susceptible to the disease. With the use of PCR, polychaetes and mollusks were tested positive for the disease. However, whether the species were infected or passive carriers are yet to be known (Thitamadee *et al.*, 2016). No drugs are available for the treatment of the disease as the thick walls of the EHP spores makes it challenging to inactivate (Songsanginda and Polchana, 2016).

Environmental impacts

In the case of shrimp farm establishment, between 1 and 1.5 million hectares of coastal lowlands has been converted into shrimp aquaculture. Most of the lands are previously comprised of salt flats, salt marshes, areas with mangrove trees and agricultural lands. The impact of greatest concern is the direct destruction of mangroves and marshes for shrimp pond construction dedicated to shrimp culturing. The relationship between mangroves and salt marshes with coastal fisheries is complex and important, there are evidences that many fish and crustacean species use these habitats as nursery areas and for shelter during early development. There is a need for further research to quantify the mangrove and salt marsh versus offshore fisheries connection, and to quantify the ecological and societal value of these ecosystems (Páez-Osuna, 2001). *L. vannamei* is one of the most economically important species for aquaculture in extensive, semiintensive, and intensive systems in many parts of the world (Duan *et al.* 2017, Yang *et al.* 2010) because this species is having several advantages compared with other cultured shrimps. Quick reproduction rate, rapid growth rate, tolerance of high stocking density, tolerance of low salinities and temperatures, lower protein requirements, high survival during larval production and low production cost are some of them. So, it's fair to assume that vannamei escapees under the natural environmental conditions. It can be confirmed based on early reports.

Potential impacts such as Saltwater intrusion and salinization of freshwater aquifers, Removal of juveniles and larvae of fish and shellfish, Declining wild shrimp population along Coastline Bycatch, Proliferation of pathogens, predators and parasites along with non-endemic species in the coastal environment, Introduction of disease to existing farms and to local ecosystems and loss in shrimp aquaculture productivity occurs die to activities related to pond construction. Introduction of exotic species is considered as one of the major factors that contribute to the irreversible and devastating impact that human activities cause to natural ecosystems, second only to habitat loss (Pérez *et al.*, 2000).

Status of escape

Shrimp escapes usually can occur in different ways during the occasions such as harvest of open ponds, during water exchange and flooding events and also from hatcheries and during transport. In the case of *L. vannamei*, the escape can be occurred during the harvest of ponds (Briggs *et al.* 2004). Several cases have been reported regarding the escaped *L. vannamei* from aquaculture production facilities into non-native waters. Texas, South Carolina, and Hawaii, USA (Balboa *et al.*, 1991; Wenner *et al.*, 1991); Thailand (Briggs *et al.*, 2004; Boone, 1931); Venezuela (Pérez *et al.*, 2007); Brazil (Loebmann D. *et al.*, 2010); Puerto Rico (Perry H., 2011); Vietnam (Binh *et al.*, 2009) and Southern Gulf of Mexico coast (Wakida-Kusunoki AT, 2011). are some of the countries that has evidences for the presence of vannamei. In the Philippines, Briggs *et al.*, reported that a population of *L. vannamei* already exists in the wild through intentional release and escapes. Escapes of cultured *L. vannamei* into the wild may also have some ecological effects. Whether they will become predator or prey or pathogen carrier also remains to be studied. WSSV, which was first reported on *P. monodon* (Chou *et al.*, 1995), has a broad host range within decapod crustaceans including freshwater crayfish (Lo *et al.*, 1996b; Wang *et al.*, 1998). The virus, which comes from *L. vannamei* may also infect freshwater prawn.

Among the more than 20 shrimp species introduced for aquaculture, three species have established population in alien habitats. *P. monodon* (from Asia Pacific) has been found from trawler catches in Nigeria (Chemonics 2002). *L. vannamei* (native to west coast of the Americas) had been caught in the Gulf of Mexico (Briggs *et al.*, 2005). While Fenneropenaeus merguiensis (from southeast and south Asia and Indian Ocean) have established its population in Fiji (Gundermann and Popper 1975; Pérez Farfante and Kensley 1997) and in Mediterranean Sea (Özcan *et al.* 2006).

The chances of *L. vannamei* establishing a population in inland ecosystem is regarded as small, since its spermatophore has lower weight and higher abnormal rate at 5 psu (Yuan and Cai 2006), and its fertilized eggs cannot develop normally when the salinity is below 22 psu (Peng *et al.*, 2002). 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 Post Larvae *L. vannamei* into the wild in attempts to escape detection. Sometimes, some natural phenomena such as typhoons also have resulted in escaping of vannamei shrimps into the surrounding sea.

Establishment of a natural population

With regard to some studies, this (*L. vannamei*) species is not considered as a threat to biodiversity and does not appear to have formed breeding their own populations, according to Briggs, the species has been widely introduced. According to the studies of Dugassa and Gaetan, *L. 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. usually takes around 1.5 years to complete the whole life cycle (Briggs *et al*., 2005). The ecological impacts of escaped farmed shrimps could be as follows;

- Spreading alien pathogens
- Competition with other species for space and food
- Interfering with breeding behavior or breeding success of native shrimp species (Briggs 2004; Molnar *et al*., 2008; Senanan *et al*., 2009; Panutrakul *et al*., 2010).

In the case of the spreading alien pathogens, there is a concern that shrimp viruses associated with these species have infected native shrimp populations, for example Taura Syndrome Virus (TSV) was detected in *L. setiferus* and Farfantepenaeus aztecus in Laguna Madre, Mexico (GuzmánSáenz *et al*., 2009), *L. schmitti* in Maracaibo lagoon, Venezuela (Fajardo *et al.*, 2010) and seven shrimp species in Bangpakong river, Thailand (Senanan *et al*., 2009). Some studies made in Thailand concluded that *L. vannamei* could potentially compete with native shrimp species because it approaches food items faster and is more aggressive than the native shrimp (Chavanich *et al*., 2008; Panutrakul *et al*., 2010). However, the impact of pond-based production on the environment, and also the risks for pathogen outbreaks, are cause for concern. Discharge from shrimp ponds is a significant source of biological and chemical pollutants in ocean waters that can harm natural aquatic environment and habitats that are sensitive to excessive nutrient loads (IUCN, Invasive Special Specialist Group (ISSG)). And also, it can harm marine species as well. The exposed nature of open ponds means they have limited protection against exposure to pathogens, with high density ponds at greater risk of experiencing outbreaks as a result of increased pollution and stress conditions. It's hard to find evidence of white leg shrimp becoming established in the zone of the Mexican coast of the Gulf of Mexico. The low frequency of *L. vannamei* encounters in the monitoring program of artisanal shrimp fishing in lagoon system and the negative presence of *L. vannamei* in surveys of the commercial shrimp catches of coastal waters near to the mouth of this lagoon indicate the absence of an established population of Pacific white shrimp. Additional sampling and long-term monitoring are required to assess the potential impacts of the presence of *L. vannamei* on the native shrimp species.

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 (Texas Parks and Wildlife Department). The presence of the shrimp in commercial catches in South Carolina was also reported in 1989 and 1990 (Wenner, E.L. and Knott, D.M., 1992). On the other hand, (Medina-Reyna Medina-Reyna, C.E., 2001) 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. The recent study of Chavanich *et al*., 2016, results indicated that the escaped L. vannamei species can likely survive the environmental conditions of the Bangpakong River and its river mouth as well. A toxicological experiment was conducted to evaluate the physiological limits of larvae and juveniles of *L. vannamei* and *P. monodon* to extreme salinity and pH changes (Panutrakul *et al*., 2010). Results showed that both species can tolerate more extreme changes and a wide range of salinity and pH. For both life stages, *L. vannamei* could tolerate a wider range of salinity and pH than *P. monodon*. The data showed that both life stages of *L. vannamei* could adapt to estuarine conditions of the Bangpakong river where water quality (specially salinity) can fluctuate dramatically.

White leg shrimps' competition with native shrimp species

Studies have shown that there is a potential risk of a negative impact of the introduced *L. vannamei* on native species and the invaded ecosystems (Senanan *et al*., 2010, Senanan et al., 2007, Panutrakul *et al*., 2010). An alien species like *L. vannamei* could potentially interact with local species including other native shrimps through food competition, either by exploitative or interference competition (Senanan *et al*., 2010). And some studies show that 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. On the other hand, increasing the propagule pressure may enhance the foundation of an invasive population (Reise *et al*., 2009). In Bangpakong estuary, increased frequency of encountering the shrimp is reflecting an increase in propagule pressure because the frequency of escapes is increasing (Senanan *et al.*, 2007).

Results from laboratory experiments

Actually, cultured penaeid shrimps are opportunistic feeders and also may exhibit cannibalistic behavior (Thomas 1980; Boddeke 1983). Most Studies based on laboratory experiments shows that *L. vannamei* fed on the meat of native shrimps obvious preference. Broader studies indicate that penaeid shrimps in general (including *L. vannamei*), are carnivores that consume a wide array of invertebrates such as polychaetes, mollusks, and crustaceans (Thomas 1980; Boddeke 1983; Panutrakul *et al*., 2010; Zhang *et al.*, 2010). Usually when food sources are limited in its surrounding area, *L. vannamei* shows an aggressive feeding behavior. But a degree of aggressiveness in food and habitat competition may also vary depending on species, sizes, and sexes (Moss and Moss 2006). These results have proved that the *L. vannamei* is a threat the other shrimps such as *P. monodon* and native shrimps. The results showed that *L. vannamei* was faster than all the native shrimp species except for *P. monodon* in detecting prey and it consumed the food more quickly than all the other native species, *L. vannamei* individuals successfully found and consumed the food first. On the other hand, when presented with prey on the bottom, and one *L. vannamei* against one *P. monodon*, the swimming species *L. vannamei* usually won against the benthic *P. monodon*. *L. vannamei* is an opportunistic feeder that can adapt well to changes in diet composition (GamboaDelgado *et al*., 2003). Further, there was broad diet overlap between *L. vannamei* that escaped from farms and local shrimp species: the main prey items ofall species being phytoplankton, appendages of crustaceans, and vegetal matter (Panutrakul *et al*., 2010).

In the recent studies, the density of the shrimp individuals used in the experiment had an influence on the outcome of competition for food. The species with the greater number won the food challenge with the exception of the one to one encounters. This proves the feeding success was strictly density-dependent. The people who conducted this experiment not observe any incidences when one species took away the food obtained first by the other individual. While behavioral dominance was clearly shown in a laboratory setting, the application to a field setting is less clear. A food resource must be in short supply and evidence of food limitation one way or the other is lacking; for competition to have an effect on one or both species. Propagule pressure is one of the key factors influencing the success of invading species (Williamson 1996; Ruiz *et al*., 2000). Increasing the propagule pressure may enhance the establishment of an invasive population (Ruiz *et al*., 2000; Senanan *et al*., 2007) reported an increased frequency of encountering *L. vannamei* in Bangpakong estuary, perhaps reflecting an increase in propagule pressure because the frequency of escapes is increasing. That some of these animals are escapees is based on the medium to large (average 85 mm TL) sizes of *L. vannamei* being found in the Bangpakong estuary. The release of the white shrimp from culture can occur during water exchange, pond cleaning, harvests, flooding incidents, or intentional release (Senanan *et al*., 2007; Chavanich *et al*., 2010). The studies prove that there is a potential risk of a negative impact of the introduced white shrimp on native species and the invaded ecosystems. The *L. vannamei*, behaviorally, was dominant when competing for prey items and any increase in white shrimp numbers may well result in a decrease in abundance of one or more native species. It currently is unknown whether existing predators of native shrimps would also prey upon the nonnative white shrimp (Senanan *et al*., 2007, 2010; Panutrakul *et al*., 2010). In a worst-case scenario, the nonnative shrimp could drive more native species to local extinction. Studies suggested that culturing *L. vannamei* in inland areas would have less ecological risk than that rearing them in coastal areas. The inland culture would definitely lead to no or low incidents of escapes of cultured shrimp into the wild (Liao and Chien, 2011). The choice of culture locations is really important because aquaculture operations using *L. vannamei* is expected to grow in Southeast Asian countries. Thus, preventive measures such as strengthening the government control of introduction of non-native species and establishing a monitoring program for detecting the establishment and spread of *L. vannamei* are needed (Chavanich *et al*., 2010; Liao and Chien 2011).

Impact of Inland L. vannamei culture

There are numerous introductions of non-native freshwater aquatic organisms throughout the world and their consequences were evaluated in various points of view (Gozlan 2008, 2009; Simõs Vitule *et al*., 2009). However, the instances of euryhaline marine organisms being cultured in inland freshwater are rare and their impacts never evaluated. Ex: - milkfish (*Chanos chanos*) and grey mullet (*Mugil cephalus*) culture in Taiwan. In the case of introduced *L. vannamei*, which is now widely cultured in Asia, its impacts as a new aquaculture species with regard to disease infection (Briggs *et al*., 2005) and on shrimp fishing activities (Gillet, 2008) have been extensively reviewed. However, the impacts of inland *L. vannamei* culture has not yet examined.

Destruction of mangrove due to shrimp farming

Shrimp farming has significantly contributed to mangrove destruction in the past one to two decades. In global level since 1960, shrimp culturing may be responsible for between 10% and 25% of the mangrove destruction (Clay, 1996). According to the Phillips *et al*., 1993, Studies estimate that 765,500 ha of mangroves have been cleared for aquaculture and mostly for the shrimp farming. Important thing is 639,000 ha in Asia alone. It's estimated that 20% to 50% of mangrove destruction is due to shrimp aquaculture, in the areas where shrimp aquaculture has become prominent (NACA, 1994). Shrimp farming in Sri Lanka became one of the fastest growing industries in the 1980s (Cattermoul and

Devendra, 2002; Munasinghe *et al*., 2010). According to Dayananda, 2004; Drengstig, 2013, 170km of coastline comprising sheltered bays and lagoons that are prominent sites for aquaculture development in Sri Lanka. Bergquist, 2007; Rajitha *et al*., 2007 Says that although there are good impacts in shrimp culturing such as industrial and socio economically wise, there's a significant potential for the shrimp industry to contribute to Sri Lankan economic growth and reduce poverty, unsustainable culturing of shrimps causes environmental and socio-economic harm due to the exploitation natural resources of the coastal area. According to Dayananda, 2004 most of the people with low income who live in the coastal area are usually highly dependent on coastal ecosystems such as mangrove forests. So, the shrimp farming can lead to an extensive mangrove destruction and this destruction leads to loss of goods and services for local populations and this includes loss of coastal protection, decreased availability of timber and firewood. And loss of mangroves directly impacts the species who live in mangrove forests since the loss of breeding and nursery grounds for fish and other species happens due to mangrove destruction.The ultimate outcome of this can be directly impact to the fisheries industry (Alongi, 2002; Satyanarayana *et al*., 2013). Due to construction of shrimp ponds, canals, access roads and dredging and deposition of dredge materials, destruction/ degradation of coastal aquatic ecosystems and alteration of estuarine flow and local hydrology can happen. As the potential results of this, Loss of habitat and reduced ecosystem productivity and resilience, loss of wild stocks of shrimp, waterfowl and other estuarine- dependent organisms, desertification of local area, loss of nutrient recycling, alteration of microclimate, increased soil erosion and sedimentation, increased beach erosion, increased natural hazards and salinization of underground water table by intrusion and percolation happens. Withdrawal groundwater water, effluent discharges from ponds, introduction of exotic species and spreading of viral and bacterial diseases also some of the activities based on shrimp culturing which gives potential bad impacts (Clay, 1996; Alongi, 2002).

Sustainability of L. vannamei culturing in freshwater

The reduced use of fish meal in L. vannamei culture compared to *P. monodon* will result in the reduction of pressure on marine sources, so is the impact of fish meal industry on marine ecosystem (Deutsch *et al*., 2007). Feedback from farmers suggest better feed efficiency when *L. vananmei* are cultured in freshwater, which may also reflect the higher natural productivity of freshwater ponds compared to brackish water ponds and better feed utilization in low-salinity ponds (Bray *et al*., 1994). In inland low-salinity shrimp farming, farmers often practice near zero-water exchange to conserve the salinity acquired from seawater, brine supplementation or mineral fertilization. This is especially important for smooth acclimation during early grow-out stage. Water replacement during later grow-out further dilutes salinity in the neighborhood. However, the seepage, overflow, or discharge at the end of a crop of this higher-than-normal mineral concentration into the neighboring environments is inevitable. As to what extent the impact of this salinity pollution may cause to the freshwater ecosystem, including soil salinization, remains to be assessed. This is despite the low salt concentration and continues dilution by rainfall or surface water flow. However, an investigation on the effluent from an inland, low-salinity shrimp farm showed a potential benefit of this rich nutrient effluent in irrigation of field crops (McIntosh and Fitzsimmons, 2003).

Socio-economic aspects in L. vannamei culture

Shrimp aquaculture imposes important social and economic impacts on the lives of people living in the areas of culture undertaken. Though shrimp farming creates benefits for the community it gradually changes the nature and social environmental patterns of the community (Tobey, 2017). Aquaculture has been accused to be the cause of many problems such as environmental, economic, inclusively esthetic, and social impacts (Martinez, 2012). As *L. vannamei* is an exotic species in many parts of the world and

with the domestication and mass culture of the species the concern on its social and economic impacts are of major concerns. Social impacts associated with shrimp farming include the increase of poverty and landlessness, food insecurity, and impacts on health and education (Barraclough, and Finger-Stich, 1996). Large scale aquaculture enterprises frequently displace small scale fishers and locals threatening their traditional livelihoods, putting an additional environmental strain on nearby natural resources and causing conflicts between displaced and other marginal areas (Tobey, 2017). It is considered as an direct threat in conversion of mangrove lands and destroying natural estuarine systems which eventually lead to the collapse of small scale and medium scale fisheries.Eventually creating conflicts between interested parties, surrounding locals and many other entities make use of such ecosystems (Primavera, 1991). Rather than positive impacts generated by shrimp farming, it is observed to have more negative impacts on local residents when considered about income generation and fulfillment of protein requirements

(Chua *et al*. 1989). Though newly initiating shrimp aquaculture systems create various job opportunities in terms of labor, to the neighboring or interested communities, much of the people lost their jobs when constructions are over and farm operations are started. Once the ponds and other facilities are constructed modern systems require a very limited labor force such as 0.1 to 1.0 persons per ha (Chua *et al*., 1989; Tobey, 2017). The majority of people living nearby estuaries and water sources are interested in shrimp aquaculture, lack of resources, inadequate capital investments and knowledge, poor coordination and support, not having skills and other modern technologies easily exclude them instantly from culture practices. As high-density shrimp culture is loaded with high capital investments, profit-oriented multinational business companies or national scale prominent business figures enter the culture practice much easier (Briggs, 2006). Availability of necessary capital for fresh investments as well as the ability to endure any economic losses, constant government support and subsidies such as loan facilities also makes them more attracted than local communities (Primavera, 1997).

With high costs on broodstock importation, allied quarantine activities and transportation has increased the price of *L. vannamei* seeds which is subsequently get passed over to farmers who buy the seeds. In addition to shipping costs mortality causes during transportation also add more cost in *L. vannamei* culture, this has led some hatcheries to source broodstock from shrimp ponds but it results in poor quality productions ending up in economic losses to farmers. Other than costs associated with purchasing broodstock or larvae, due to the higher stocking densities the use of generators and aerators are much higher in *L. vannamei* culture which results in higher cost of production than other commercial shrimp varieties. cost of production of *L. vannamei* is 2.3 times more higher than that of tiger shrimp and annual net profit from *L. vannamei* is 1.5 times higher than tiger shrimp.These external costs make culturing of *L. vannamei* more difficult to local farmer communities and the situation gets worse if any disease outbreak occurs. Low yields resulted due to viral outbreaks has considered as a major concern in terms of economic benefits and sustainable development of the industry (Shyam *et al*., 2019; Sanchez, *et al*., 2009). It is calculated that the financial losses due to disease outbreaks in *L. vannamei* culture are unavoidable and it results in huge economic depressions worth about 1,000 crores from the total production system. Even though large scale shrimp projects are invested with huge amounts of money neglecting the risks associated, it is evident that the long term sustainability of such projects are very low due to concerns in the quality of the product, lack of practical scientific knowledge and use of modern technology (Margabandu *et al*., 2013). Furthermore transferring of nearby estuaries or waterbodies to half-constructed ponds, the destruction caused to the environment with aquaculture infrastructure as well as acquiring of lands from multinational companies reduce or obstruct the availability of protein sources, fuel and building materials to local communities which make the livelihood extremely difficult. While in most cases as cultured exotic shrimp species are exported due to high demand and market value without releasing them to the local market, much of the benefits in terms of 'protein benefit', earnings generated from local resources as well as employment opportunities will not be available to local communities from most of the huge exotic shrimp projects (Clay, 1996). Losing of valuable lands and coastal wetlands previously managed by local government bodies and will not be available to the general public for their interests with shrimp projects commencing in these lands. The rapid and chaotic growth in shrimp farming means that land once open to public use for fishing and cutting of firewood and bark for tannin production is being lost to private use (Vergne *et al*., 1993). Local fisher communities, artisanal fishers and other dependent entities will be threatened and conflicts for land use and resources occur. Sametime with the destruction of mangrove forests and clearing the land eventually leads to flooding effects, low productivity in adjacent waters and loss of any income means to nearby local communities are prominent (Clay 1996; Primavera 1991).

Introduction *L. vannamei* to a certain geographic region requires expert knowledge and guidance, creating awareness among associated parties specially in extension officers and farmer communities to handle new exotic species with limited data available on its movements and impacts towards community and environment is challenging. Importing broodstock, quarantine activities and maintaining specific biosecurity conditions are essential components to consider in a responsible culture practice (Kumaran *et al*., 2012). Many countries introduced *L. vannamei* due to problems experienced in historically cultured shrimp varieties or expecting diversification of the shrimp sector or to enhance the performance (Briggs *et al*., 2004). With the recent trend of turning world shrimp culture towards *L. vannamei*, pressure on governments to legalize and support the introduction of exotic shrimp species are more producer oriented and lack of government control over binding private entities in existing laws and regulations is difficult (Rosario and Lopez, 2005; Funge-Smith and Briggs, 2003). Overtaking of previously cultured commercial shrimp varieties such as *P. monodon* and commencing *L. vannamei* practices leads to a higher competition in the world market experiencing a reduction of *L. vannamei* prices drastically. More and more competition is expected with intensified productions and introductions of non- tariff barriers in the shrimp trade (Shyam *et al*., 2019). Due to the low-price problem, production of *L. vannamei* in 2018 was declined compared to 2017 in Thailand and Shifting of farmers back to Penaeus monodon was notable in countries like Vietnam, Thailand, Indonesia and Malaysia due to stable and high market values than *L. vannamei* (FAO, 2019). Legalizing of *L. vannamei* importations to a certain country indirectly supports the smuggling/ illegal importations of non-certified (SPF/SPR) broodstocks as well as PL where tracing of such activities is difficult. Due to these importations disease outbreaks, health concerns to the local community and economic losses can be resulted in collapsing other existing aquaculture facilities also. This is a highly concerning factor with regard to *L. vannamei* because of the reputation for smuggling *L. vannamei* worldwide (Briggs *et al*., 2004).Studies shows that social impacts vary considerably depending on the form of aquaculture and the policies. It is important to compare and weigh the much-focused foreign earnings over social and economic impacts it directly and indirectly possesses over local livelihood and community (Bailey 1988; Meltzoff and LiPuma 1986).

DISCUSSION

The biological, environmental and socio-economical impact caused by *L. vannamei* is described in this case study with reference to a global scale. The impacts mentioned will continue to change the state of the world in an irreversible manner if the huge trend of anthropogenic influence to the environment grow continuously. It is important to evaluate and build pressure on necessary actions needed to manage the identified impacts with reference to *L. vannamei*, which is considered as a must, in order to thrive for a sustainable development that each country seek for. Major impacts and problems identified are; The growth rate of *L. vannamei* slows after reaching 20g making the production of large shrimp slower resulting low market value in the trade as consumers prefer larger size shrimps. High stocking densities are possible but need high control over pond/tank management practices and are high-risk strategies. Constant monitoring, use of generators and aerators are essential and comparatively increase the cost of production than other cultured shrimp species. Due to aggressive *L. vannamei* culturing trend in the world the market and ambient supply from various parts of the world, shrimp prices has been dropped compared to larger sized *P. monodon*. It is necessary to assess the cost of production and final market value in order to obtain the due profit after all the risks taken. Because of this scenario many countries including top producing Asian countries have shifted back to locally cultivated native shrimp varieties, motivated by stable markets and higher price compared to *L. vannamei*. Susceptibility to diseases and a carrier of TSV, WSSV, YHV, IHHNV and LOVV while *P. monodon* is refractory to TSV and IHHNV. Also there may be chance of introducing nonnative diseases to several geographic locations with new introductions causing transmission of diseases to locally available crustacean species. SPF animals sometimes have high mortality in disease-laden environments due to stress conditions. Broodstock rearing and spawning are considered to be more technical and complicated where expert knowledge and training is highly recommend also Handling, transportation and processing are comparatively costly which eventually increase the cost of production making unbearable to most of the farmer communities. The escaping of shrimps can occur in different ways during the harvest of open ponds, during water exchange and flooding events and also from hatcheries and during transport. Mostly the escape may be occurred during the harvest of ponds, in the case of *L. vannamei*. The harvests in the farms of this zone are carried out twice per year, in April and September generally and the shrimps are harvested when they reach a weight of 12 g. The factors that could indicate that this species can survive in the wild include: the weight differences between harvest size and collected specimens (12 to 39g) and the distance between farming zones and capture area.

The ecological impacts of escaped farmed shrimps could be as follows: spreading alien pathogens, competition with other species for space and food, and interfering with breeding behavior or breeding success of native shrimp species In the case of the spreading alien pathogens, there is a concern that shrimp viruses associated with these species have infected native shrimp populations, for example Taura Syndrome Virus (TSV) was detected in *L. setiferus* and *Farfantepenaeus aztecus* in Laguna Madre, Mexico, *L. schmitti* in Maracaibo lagoon, Venezuela and seven shrimp species in Bangpakong river, Thailand. Some studies made in Thailand concluded that *L. vannamei* could potentially compete with native shrimp species because it approaches food items faster and is more aggressive than the native shrimp. Results of some lab experiments shows that *L. vannamei* is opportunistic feeder where it tends to consume any available food material posing huge threat to native crustaceans and larvae of aquatic organisms in a case of escape occurs. There will be a direct threat to Coastal communities depending on marine and coastal fisheries where loss of species can occur with interactions of such exotic species eventually leading to huge economic depressions in nearby communities.With regard to all these negative impacts and social and environmental risks combined with introduction of exotic species must be weighed with the final gain of all concerned profit, past experiences and eventually opening the doors for responsible culture practices.

REFERENCES

Broad, S., T. Mulliken, and D. Roe, (2003) The ©FAO 2006-2020. Cultured Aquatic Species Information Programme. Penaeus vannamei. Cultured Aquatic Species Information Programme. Text by Briggs, M. In: FAO *Fisheries Division* [online]. Rome. Updated 7 April 2006. [Cited 13 September 2020]

Abualtaher, M. and E.S. Bar, (2020). Food-Loss Control at the Macronutrient Level: Protein Inventory for the Norwegian Farmed Salmon Production System. *Foods*, **9(8):** p.1095.

Ahamed, A.S., M.B. Haq, M.N. Banu, C. Tiwary, and R. Sedhuraman, (2016). An update of major DNA shrimp viruses-White Spot Syndrome virus (WSSV), Monodon Baculovius (MBV), Infectious Hypodermal and Hematopoietic Necrosis virus (IHHNV) and Hepatopancreatic Parvovirus (HPV): A Review. *Imperial Journal of Interdisciplinary Research*, **3(1):** pp.1-15.

Alejos, M.S., A.E. Serrano, Y.U. Jumah, R. dela Calzada, C.T.B. Ranara and J.C. Fernandez, (2020). Ecological and Social Impacts of Aquacultural Introduction to

Philippines Waters of Pacific Whiteleg Shrimp Penaeus vannamei. In *Spatial Variability in Environmental Science-Patterns, Processes, and Analyses.* IntechOpen.

Alleway, H.K., C.L. Gillies, M.J. Bishop, R.R. Gentry, S.J. Theuerkauf and R. Jones, (2019). The ecosystem services of marine aquaculture: Valuing benefits to people and nature. *BioScience*, **69(1):** pp.59-68.

Anderson, I.G., M. Shariff and G. Nash, (1989). A hepatopancreatic microsporidian in pond-reared tiger shrimp, Penaeus monodon, from Malaysia. *Journal of Invertebrate Pathology*, **53(2):**pp.278280.

Ashok, A., M. LN, and P. MM, (2015). Impact of Pacific white shrimp (*Litopenaeus vannamei*) on shrimp production and seafood processing in Andhra Pradesh.

Babu, Y.M., K.R. Ramudu, S.S. Dana and G. Dash, (2013). An overview on Litopenaeus vannamei farming practices in India, current issues, problems and future perspectives. *International Journal of Current Research*, **5(08):** pp.2118-2122.

Bailey, C., (1988). The social consequences of tropical shrimp mariculture development. *Ocean and Shoreline Management,* **11(1):** pp.31-44.

Balboa, W.A., T.L. King and P.C. Hammerschmidt, (1991), November. Occurrence of Pacific white shrimp in lower Laguna Madre, Texas. In *Proceedings of the annual conference southeast association fish and wildlife agencies* (Vol. 45, pp. 288-292).

Barraclough, S. and A. Finger-Stich (1996). *Some ecological and social implications of commercial shrimp farming in Asia*. UNRISD.

Binh LT, Yen MD, Luyen NH. Preliminary impacts assessment of alien aquatic species on biodiversity as well as invasion of native fishes in aquaculture and some management measures. In: 13th World Lake Conference. Rehabilitate the Lake Ecosystem: Global Challenges and the Chinese Innovations; 2009

Bonnichon, V., D.V. Lightner, and J.R. Bonami, (2006). Viral interference between infectious hypodermal and hematopoietic necrosis virus and white spot syndrome virus in Litopenaeus vannamei. *Diseases of aquatic organisms*, **72(2):** pp.179-184.

Boone. Penaeus vannamei. World register of marine species. 1931. Available from: http:// www.marinespecies.org/aphia.php?p=taxdetails&id=377748

Briggs, M., 2006. Cultured Aquatic Species Information Programme. *Penaeus vannamei*. *Preprintat,http://www. fao.org/fishery/culturedspecies/Penaeus_vannamei/en (FAO, 2006).*

Briggs, M., S. Funge-Smith, R. Subasinghe and M. Phillips (2004). Introductions and movement of Penaeus vannamei and Penaeus stylirostris in Asia and the Pacific. *RAP publication*, 10 (2004), p.92.

Budhiman, A.A., T.S. Paryanti and A. Sunaryanto,(2005). The present status of *Penaeus vannamei* and other exotic shrimp culture in Indonesia.

CABI. *Litopenaeus vannamei* Boone (1931). In: Invasive Species Compendium. Wallingford, UK: CAB International; 2019. Available from: www.cabi.org/isc

Caratis, Alban, (2018). Cultured Shrimp in Vietnam < https://seafood- tip.com/sourcingintelligence/countries/vietnam/shrimp/)> Accessed on 01st September 2020.

Chavanich, S., V. Viyakarn, W. Senanan and S. Panutrakul (2016). Laboratory assessment of feeding-behavior interactions between the introduced Pacific white shrimp *Litopenaeus vannamei* (Boone, 1931)(Penaeidae) and five native shrimps plus a crab species in Thailand. *Aquatic Invasions*, **11(1).**

Che, B., S. Chen and W. Jing (2018). Cost-benefit Analysis on Higher-place Pond

Culture of Penaeus Vannamei—A case of a Farmer in Zhanjiang City of Guangdong Province.

Chen, Y.H. and J.G. He (2019). Effects of environmental stress on shrimp innate immunity and white spot syndrome virus infection. *Fish & shellfish immunology*, **84:** pp.744-755.

Clay, J.W., (1996). *Market potentials for redressing the environmental impact of wild captured and pond produced shrimp* (No. 639.2 C619m). sn,.

Dewangan, N.K., G. Ayyaru, R. Kuzhanthaivel, S.S. Thirugnanasambandan, G.G. Martin, K. Daniel and R.S. Ramakrishna, (2017). Incidence of simultaneous infection of infectious hypodermal and haematopoietic necrosis virus (IHHNV) and white spot syndrome virus (WSSV) in *Litopenaeus vannamei*. *Aquaculture*, **471:** pp.1-7.

Duan, Y., Q. Liu, Y. Wang, J. Zhang and D. Xiong, (2018). Impairment of the intestine barrier function in Litopenaeus vannamei exposed to ammonia and nitrite stress. *Fish & shellfish immunology*, **78:** pp.279-288.

Duan, Y., Y. Zhang, H. Dong, X. Zheng, Y. Wang, H. Li, Q. Liu and J. Zhang (2017). Effect of dietary poly-β-hydroxybutyrate (PHB) on growth performance, intestinal health status and body composition of Pacific white shrimp *Litopenaeus vannamei* (Boone, 1931). *Fish & shellfish immunology*, **60:** pp.520-528.

Dugassa, H. and D.G. Gaetan (2018). Biology of white leg shrimp, Penaeus vannamei: Review. *World Journal of Fish and Marine Sciences*, **10(2):** pp.5-17.

Eng, C.T., J.N. Paw and F.Y. Guarin (1989). The environmental impact of aquaculture and the effects of pollution on coastal aquaculture development in Southeast Asia. *Marine pollution bulletin*, **20(7):** pp.335-343.

Esparza-Leal, H.M., C.M. Escobedo-Bonilla, R. Casillas-Hernández, P. Álvarez-Ruíz, G. PortilloClark, R.C. Valerio-García, J. Hernández-López, J. Méndez-Lozano, N. Vibanco-Pérez and F.J. Magallón-Barajas (2009). Detection of white spot syndrome virus in filtered shrimp-farm water fractions and experimental evaluation of its infectivity in Penaeus (Litopenaeus) vannamei.

Funge-Smith, S. and M. Briggs (2003). The introduction of *Penaeus vannamei* and *P. stylirostris* into the Asia-Pacific Region. International Mechanisms for the Control and Responsible Use of Alien Species in Aquatic Ecosystems, Jinghong, Xishuangbanna, People's Republic of China, pp.26-29.

Gentry, R.R., H.E. Froehlich, D. Grimm, P. Kareiva, M. Parke, M. Rust, S.D. Gaines and B.S. Halpern (2017). Mapping the global potential for marine aquaculture. *Nature Ecology & Evolution*, **1(9):** pp.1317-1324.

Guo, H., C.X. Ye, A.L. Wang, J.A. Xian, S.A. Liao, Y.T. Miao and S.P. Zhang, (2013). Trascriptome analysis of the Pacific white shrimp *Litopenaeus vannamei* exposed to nitrite by RNA-seq. *Fish & shellfish immunology*, **35(6):** pp.2008-2016.

Hatje, V., M.M. de Souza, L.F. Ribeiro, G.F. Eça and F. Barros (2016). Detection of environmental impacts of shrimp farming through multiple lines of evidence. *Environmental pollution*, **219:** pp.672-684.

Hudson, D.A., N.B. Hudson and S.B. Pyecroft (2001). Mortalities of *Penaeus japonicus* prawns associated with microsporidean infection. *Australian veterinary journal*, **79(7):** pp.504-505. India Environment Portal. Available from: www.indiaenvironmentportal. org.in/node/38152

Kawase, T., (2011). Advantages and disadvantages of surgical approaches to petroclival lesions. *World neurosurgery*, **75(3-4):** p.421.

Kumaran, M., P. Ravichandran, A. Panigrahi, M.K. Sinha, S. Nagarajan, D.D. Vimala and A.G. Ponniah (2012). Effectiveness of sensitisation on the awareness levels of Fishery Extension Officers on Pacific white shrimp (*Litopenaeus vannamei*) farming in India. *Indian Journal of Fisheries*, **59(4)**.

Landsman, A., B. St-Pierre, M. Rosales-Leija, M. Brown and W. Gibbons (2019). Impact of aquaculture practices on intestinal bacterial profiles of Pacific whiteleg shrimp *Litopenaeus vannamei*. *Microorganisms*, **7(4):** p.93.

Liao, I.C. and Y.H. Chien (2011). The pacific white shrimp, *Litopenaeus vannamei*, in Asia: The world's most widely cultured alien crustacean. In In the wrong place-alien marine crustaceans: *Distribution, biology and impacts* (pp. 489-519). Springer, Dordrecht.

Lin, Y.C., J.C. Chen, Y.Y. Chen, S.T. Yeh, L.L. Chen, C.L. Huang, J.F. Hsieh and C.C. Li (2015). Crowding of white shrimp *Litopenaeus vananmei* depresses their immunity to and resistance against *Vibrio alginolyticus* and white spot syndrome virus. *Fish & Shellfish Immunology*, **45(1):** pp.104-111.

Loebmann, D., A.C.G. Mai and J.T. Lee (2010). The invasion of five alien species in the Delta do Parnaíba Environmental Protection Area, Northeastern Brazil. *Revista de Biología Tropical*, **58(3):** pp.909-923.

López-Téllez, N.A., J.A. Corbalá-Bermejo, M.L. Bustamante-Unzueta, L.P. Silva-Ledesma, V.M. Vidal-Martínez and R. Rodriguez-Canul (2020). History, impact, and status of infectious diseases of the Pacific white shrimp *Penaeus vannamei* (Bonne, 1831) cultivated in Mexico. *Journal of the World Aquaculture Society*, **51(2):** pp.334-345.

Margabandu, V. and D. Ramamurthy (2013). Recent Farming Practices for Culturing Sustainable Pacific White Shrimp, Peneaus Vannamei. *International Journal of Science dan research*, **4(2)**.

Martinez-Porchas, M. and L.R. Martinez-Cordova, (2012). World aquaculture: environmental impacts and troubleshooting alternatives. *The Scientific World Journal*, (2012).

Medina-Reyna, C.E., (2001). Growth and emigration of white shimp, *Litopenaeus vannamei*, in the Mar Muerto Lagoon, Southern Mexico.

Meltzoff, S.K. and E. LiPuma (1986). The social and political economy of coastal zone management: shrimp mariculture in Ecuador. *Coastal Management*, **14(4):** pp.349-380.

Morton, B., (1997). The aquatic nuisance species problem: a global perspective and review. Zebra mussels and aquatic nuisance species, pp.1-54.

Musthaq, S.K.S. and J. Kwang (2014). Evolution of specific immunity in shrimp–A vaccination perspective against white spot syndrome virus. *Developmental & Comparative Immunology*, **46(2):** pp.279-290.

Páez-Osuna, F., (2001). The environmental impact of shrimp aquaculture: a global perspective. *Environmental pollution*, **112(2):** pp.229-231.

Panutrakul, S., W. Senanan, S. Chavanich, N. Tangkrock-Olan and V. Viyakarn (2010). Ability of *Litopenaeus vannamei* to survive and compete with local marine shrimp species in the Bangpakong River, Thailand. Tropical Deltas and Coastal Zones: Food Production, Communities and Environment at the Land-Water Interface, ed. Chu T. Hoanh, Brian W. Szuster, Kam SuanPheng, Abdelbagi M. Ismail, and Andrew D. Noble, 9, pp.80-92.

Perez Farfante, I.S.A.B.E.L. and B. Kensley, (1997). Penaeoid and sergestoid shrimps and prawns of the world. Keys and diagnoses for the families and genera. Editions du Museum national d'Histoire naturelle

Pérez, J., C. Alfonsi, S. Salazar, O. Macsotay, J. Barrios and R. Martinez (2007). ESPECIES MARINAS EXÓTICAS Y CRIPTOGÉNICAS EN LAS COSTAS DE VENEZUELA. Boletín del Perry

H. Litopenaeus vannamei. USGS Non-indigenous Aquatic Species Database. Gainsville, Florida: *United States Geological Survey*; 2011

Preston, N. and H. Clayton (2003). Rice-shrimp farming in the Mekong Delta: biophysical and socioeconomic issues.

Primavera, J.H., (1991). Intensive prawn farming in the Philippines: ecological, social, and economic implications. AMBIO: *A Journal of the Human Environment*, **20(1):** pp.28-33.

Primavera, J.H., (1993). A critical review of shrimp pond culture in the Philippines. *Reviews in Fisheries Science*, **1(2):** pp.151-201.

Primavera, J.H. (1997). Socio-economic impacts of shrimp culture. *Aquaculture research*, **28(10):,** pp.815-827.

Putth, S. and J. Polchana (2016). Current status and impact of early mortality syndrome (EMS)/acute hepatopancreatic necrosis disease (AHPND) and hepatopancreatic microsporidiosis (HPM) outbreaks on Thailand s shrimp farming. In Addressing Acute Hepatopancreatic Necrosis Disease (AHPND) and Other Transboundary Diseases for Improved Aquatic Animal Health in Southeast Asia: Proceedings of the ASEAN Regional Technical Consultation on EMS/AHPND and Other Transboundary Diseases for Improved Aquatic Animal Health in Southeast Asia, 22-24 February 2016, Makati City, Philippines (pp. 79-87). Aquaculture Department, Southeast Asian Fisheries Development Center.

Qiu, J., W.N. Wang, L.J. Wang, Y.F. Liu and A.L. Wang (2011). Oxidative stress, DNA damage and osmolality in the Pacific white shrimp, *Litopenaeus vannamei* exposed to acute low temperature stress. Comparative Biochemistry and Physiology Part C: *Toxicology & Pharmacology*, **154(1):** pp.36-41.

Raja, K., M.M. Rahman, M. Rajkumar, A. Gopalakrishnan and R. Vijayakumar, (2015). Effect of ingestion and waterborne routes under different shrimp densities on white spot syndrome virus susceptibility in three commercially important penaeid shrimps. *Aquaculture Reports*, **2:** pp.120125.

Rizan, N., C.Y. Yew, M.R. Niknam, J. Krishnasamy, S. Bhassu, G.Z. Hong, S. Devadas, M.S.M. Din, H.A. Tajuddin, R.Y. Othman and S.M. Phang, (2018). Electronic properties of synthetic shrimp pathogens-derived DNA schottky diodes. *Scientific reports*, **8(1):** pp.1-9.

Rosario, W.R. and N.A. Lopez (2005). Status of *P. vannamei* aquaculture in the Philippines.

Ruiz, G.M., P.W. Fofonoff, J.T. Carlton, M.J. Wonham and A.H., Hines (2000). Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases. *Annual Review of Ecology and Systematics*. (2000), **31:** 481-531 http://dx.doi.org/10.1146/annurev. ecolsys.31.1.481

Salunke, M., A. Kalyankar, C.D. Khedkar, M. Shingare and G.D. Khedkar, (2020). A Review on Shrimp Aquaculture in India: Historical Perspective, Constraints, Status and Future Implications for Impacts on Aquatic Ecosystem and Biodiversity. *Reviews in Fisheries Science & Aquaculture*, pp.1-20.

Srinivas, D., C. Venkatrayulu, B. Swapna, A.V. Swathi and V. Venkateswarlu, (2019). Studies on socio-economic profile, problems and constraints of shrimp farmers in nellore district of Andhra Pradesh, India. *Asian Journal of Science and Technology*, **10(06):** pp.9731-9735.

Sanchez-Zazueta, E. and F.J. Martinez-Cordero, (2009). Economic risk assessment of a semiintensive shrimp farm in Sinaloa, Mexico. *Aquaculture Economics & Management*, **13(4):** pp.312327.

Senanan, W., N. Tangkrock-Olan, S. Panutrakul, P. Barnette, C. Wongwiwatanawute, N. Niphonkit and D.J. Anderson (2007). The presence of the Pacific whiteleg shrimp (*Litopenaeus vannamei*, Boone, 1931) in the wild in Thailand. *Journal of Shellfish Research*, **26(4):** pp.11871192.

Senanan, W., S. Panutrakul, P. Barnette, V. Manthachitra, S. Chavanich, A.R. Kapuscinski, N. Tangkrock-Olan, P. Intacharoen, V. Viyakarn, C. Wongwiwatanawute and K. Padetpai, (2010). Ecological risk assessment of an alien aquatic species: a case study of Litopenaeus vannamei (Pacific Whiteleg Shrimp) aquaculture in the Bangpakong River, Thailand. Tropical Deltas and Coastal Zones: Food Production, Communities and Environment at the Land-Water Interface, ed. Chu T. Hoanh, Brian W. Szuster, Kam Suan-Pheng, Abdelbagi M. Ismail, and D. Andrew Noble, 9, pp.64-79.

Shrimp farming in Vietnam; current status, potential and investment oppurtunities -Dr. Nguyen Tan Sy; shrimp culture in Vietnam -Vu Dzung Tien and Vuvan trien; a Balance, A.M., (1998).

Shyam, S.S., R. Geetha and N.R. Athira, (2019). Indian Fish Exports and Dependence on *P. vannamei*: share and externalities. *Journal of Indian Fisheries Association*, **46(2):** pp.19-29.

Srinivas, D., C. Venkatrayulu, B. Swapna, A.V. Swathi and V. Venkateswarlu (2019). Studies on socio-economic profile, problems and constraints of shrimp farmers in nellore district of Andhra Pradesh, India. A*sian Journal of Science and Technology,* **10(06):** pp.9731-9735.

Sulit, V.T., M.E.T. Aldon, I.T. Tendencia, A.M.J. Ortiz, S.B. Alayon and A.S. Ledesma, (2005). Regional Technical Consultation on the Aquaculture of *P. vannamei* and other exotic shrims in Southeast Asia. Manila, Philippines, pp.1-2.

Tacon, A.G. and M. Metian, (2015). Feed matters: satisfying the feed demand of aquaculture. *Reviews in Fisheries Science & Aquaculture*, **23(1):** pp.1-10.

Tang, X., C. Cui, Q. Liang, X. Sheng, J. Xing and W. Zhan, (2019). Apoptosis of hemocytes is associated with the infection process of white spot syndrome virus in Litopenaeus vannamei. *Fish & shellfish immunology*, **94:** pp.907-915.

Teixeira-Lopes, M.A., P.R.N. Vieira-Girão, J.E. da Cruz Freire, Í.R.C.B. Rocha, F.H.F. Costa and G. Rádis-Baptista, (2011). Natural co-infection with infectious hypodermal and hematopoietic necrosis virus (IHHNV) and infectious myonecrosis virus (IMNV) in *Litopenaeus vannamei* in Brazil. *Aquaculture*, **312(1-4):** pp.212-216.

James Tobey, Jason Clay, Y. Philippe Verge (1998) The Economic, Environmental and Social Impacts of Shrimp Farming in Latin America. Coastal Resources Center, Universidad de Rhode Island. Disponible en pdf http://govdocs. aquake. org/cgi/reprint/2003/803/8030160. pdf.

Tobey, J., J. Clay and P. Vergne, (2017). Maintaining a balance: the economic, environmental and social impacts of shrimp farming in Latin America.

Tran, L., L. Nunan, R.M. Redman, L.L. Mohney, C.R. Pantoja, K. Fitzsimmons and D.V. Lightner, (2013). Determination of the infectious nature of the agent of acute hepatopancreatic necrosis syndrome affecting penaeid shrimp. *Diseases of aquatic organisms*, **105(1):** pp.45-55.

Trang, T.T., N.H. Hung, N.H. Ninh, W. Knibb, and N.H. Nguyen, (2019). Genetic variation in disease resistance against White Spot Syndrome Virus (WSSV) in *Liptopenaeus vannamei*. Frontiers in genetics, 10, p.264. vannamei: share and externalities. *Journal of Indian Fisheries Association*, **46(2):** pp.19-29.

Venkateswarlu, V. and C. Venkatrayulu (2019). Prevalence of disease problems affecting shrimp *Litopenaeus vannamei* farming in Andhra Pradesh, India.

Vergne, P., M. Hardin and B. Dewalt, (1993). Environmental Study of the Gulf of Fonseca. Tropical Research and Development. Inc., Washington, DC.

Wakida-Kusunoki, A.T., L.E. Amador-del Angel, P.C. Alejandro and C.Q. Brahms, (2011) Presence of Pacific white shrimp *Litopenaeus vannamei* (Boone, 1931) in the Southern Gulf of Mexico. *Aquatic Invasions*, **6(1):** pp.S139-S142.

Wells, F.E. and R. Bieler, (2020). A low number of introduced marine species at low latitudes: a case study from southern Florida with a special focus on Mollusca. *Management of Biological Invasions*, **11(3):** p.372.

Wenner, E.L. and D.M. Knott, (1992). Occurrence of Pacific white shrimp, *Penaeus vannamei*, in coastal waters of South Carolina. introductions and transfers of marine species: achieving a balance between economic development and resource protection. Charleston, SC, pp.173-181.

Wyban, J., (2009). World shrimp farming revolution: industry impact of domestication, breeding and widespread use of specific pathogen free *Penaeus vannamei*. Proceedings of the special session on sustainable shrimp farming, *World Aquaculture*, 2009, pp.12-21.

Wyban, J.A., (2003). Recent developments in *P. vannamei* seedstock production Asia. *Global Aquaculture Advocate*, **6(6):** pp.78-79.

Yan, D.C., J. Huang, B. Yang, H.S. Sun, Y.Y. Wang, and X. Liu, (2016). Competition of infectious hypodermal and haematopoietic necrosis virus (IHHNV) with white spot syndrome virus (WSSV) for binding to shrimp cellular membrane. *Journal of Fish Diseases*, **39(10):** pp.1225-1229.

Yang, S.P., Z.H. Wu, J.C. Jian and X.Z. Zhang, (2010). Effect of marine red yeast Rhodosporidium paludigenum on growth and antioxidant competence of *Litopenaeus vannamei*. *Aquaculture*, **309(1-4):** pp.62-65.

Zhang, J.S., Z.J. Li, G.L. Wen, Y.L. Wang, L. Luo, H.J. Zhang and H.B. Dong, (2016). Relationship between white spot syndrome virus (WSSV) loads and characterizations of water quality in *Litopenaeus vannamei* culture ponds during the tropical storm. *Iranian journal of veterinary research*, **17(3):** p.210.

Zhong, D., F. Wang, S. Dong and L. Li, (2015). Impact of *Litopenaeus vannamei* bioturbation on nitrogen dynamics and benthic fluxes at the sediment–water interface in pond aquaculture. *Aquaculture international*, **23(4):** pp.967-980.

Zhong, J., A. Cangelosi and S. Wermter, (2014). Toward a self-organizing pre-symbolic neural model representing sensorimotor primitives. *Frontiers in behavioral neuroscience*, **8:** p.22.

Received Date : 12 Janu. 2021
Accepted Date : 09 Mar. 2021