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Shrimp Farming in Thailand: A pathway to Sustainability

Warinyupa Phornprapha

“Shrimp Farming in Thailand: A pathway to Sustainability”

By: Warinyupa “Bebe” Phornprapha

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Abstract

Throughout this thesis I have laid out several factors that have contributed to the sustainability of shrimp farming in Thailand, and if sustainability whilst maintaining production can ever be achieved. To find out the current situation of shrimp farming in Thailand, the history of global and Thai shrimp farming is described. The social and environmental problems of the unsustainable history of shrimp farming in Thailand is then considered. Solutions to these effects conclude that it is up to the consumer to demand for better regulations from the government and the shrimp companies to ensure a sustainable future for shrimp farming both globally and in Thailand.

Chapter 1: Introduction

I love shrimp. Growing up in Bangkok, Thailand, shrimp was a common ingredient in every dish. Some of the Thai dishes that I grew up eating included "*Som Tum" (Papaya Salad),* which has dried shrimp in it, or "*Pad See Ew"* (Stir fry noodles) also has either pork, chicken or roasted shrimp in the dish (I always preferred the shrimp version). Due to the cheapness and availability of shrimp back home, at least one meal per week would include some shrimp. However, I never thought much about where and how the shrimp I was eaten was caught. While I would like to imagine that the shrimp I was eating was caught through sustainable ways, caught in the oceans where there was an abundance of shrimp, and that the shrimp caught would not make an impact on the aquatic ecosystem. Overtime I learnt that this was not the case. Once I did, my personal relationship with shrimp started to evolve.

A reason for this evolution was the rise in media investigations in the local newspapers that demonized shrimp farms for abusing child and slave migrant workers. These workers escaped the sheds and told their story to the journalists, publicly naming the company that had abused them. However, nothing ever came out of those claims, and those companies are still selling shrimp today. AP reported that a runaway migrant worker alerted the police about the slave like conditions in the shed. The shed supplied shrimp to Tokyo Based Marucha Nichiro Foods, Thai Union, Kongphop Frozen Foods, and Siam Union Foods. All these companies have customers in the US, Canada, Europe, Asia, and Australia. Conditions horrific: "A woman eight months pregnant miscarried on the shed floor and was forced to keep peeling for four days while hemorrhaging. An unconscious toddler was refused medical care after falling about 12 feet onto a concrete floor. Another pregnant woman escaped only to be tracked down, yanked into a car by her hair and handcuffed to a fellow worker at the factory". Figure 1 shows a Burmese worker who was forced to work long hours in the peeling sheds. While the raided sheds are still closed, workers were moved to another shed linked to the same owners. The sheds are still providing shrimp to the same companies (Mendoza, 2015).

Figure 1: Win Win Than, a worker who was forced to work in the shrimp peeling sheds. (Mendoza, 2015).

Having (guiltily) never paid much attention to the newspaper growing up, I often only saw glimpses of the headlines or listened to what my parents had to say about the issue. For example, *The Bangkok Post* published a headline aptly titled "shrimp peeled by slaves in Thailand". The first paragraph of the article read: "Every morning at 2 o'clock, they heard a kick on the door and a threat: Get up or get beaten. For the next 16 hours, No.31 and his wife stood with their aching hands in ice water in the factory that owned them. After being sold to the Gig Peeling Factory, they were at the mercy of their Thai bosses, trapped with nearly 100 other Burmese migrants. Children worked alongside them, including a girl so tiny she had to stand on a stool to reach the peeling table. Some had been there for months, even years, getting little or no pay." (Bangkok Post Associated Press, 2015). While the details were horrifying, the story seemed so far fetched that I never thought that something like this could happen. I always assumed the best, that the newspapers were making up or dramatasizing stories for the public's interest. No way were the largest seafood companies in Thailand knowingly employing undocumented labor. After all, if the companies that were being accused of these acts were still producing and selling shrimp, they must have not done anything wrong.

While I chose to live in blissful ignorance, not thinking about the alleged slave labor that was happening, I could not help but notice the environmental destruction that shrimp farming had brought. Growing up, my family would always take annual trips out of the city into the coastal town of Hua Hin (see figure 2), about a two hour drive south-east from Bangkok. On these journeys, my view would include a panorama of lush tropical forests. Making the same trip every year, I would notice fewer trees and more shrimp ponds. Over time, my view was dominated by endless rows of clear square ponds separated with brown mud, illustrated by figure 3. I still didn't think much of it. I only (shamefully) started to think about shrimp when I found out that the trees that were being deforested included mangroves.

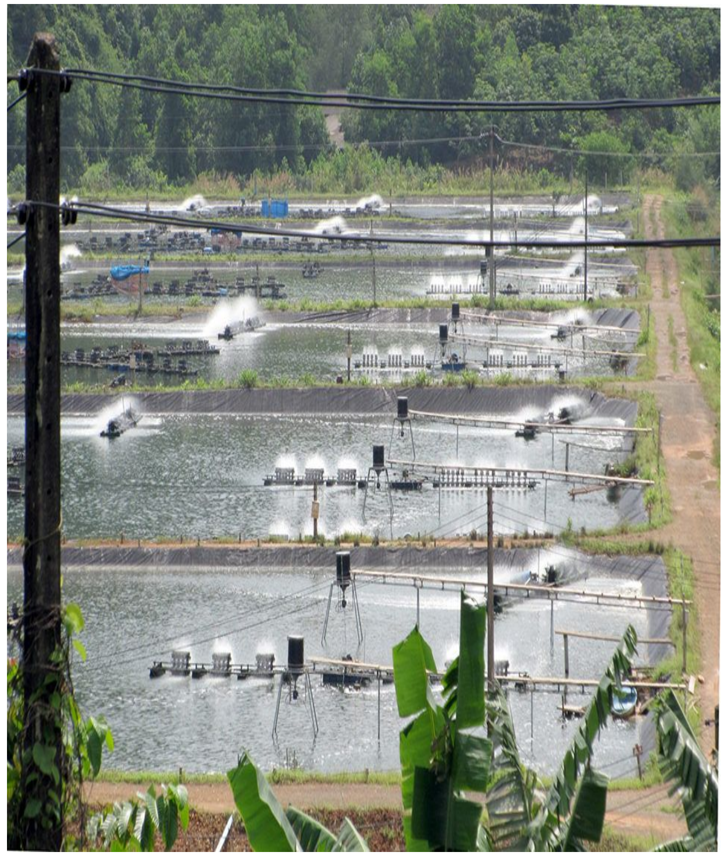

Figure 2 (Left): Map of Thailand (Walker, 2018)
Figure 3 (Right): Image of shrimp ponds in Thailand (Murray 2017)

Each year we would do a day trip where we were able to kayak through the brackish waters of the nearby mangrove forest. During the trip, our guide would talk about how mangroves were an integral part of the ecosystem, providing a habitat and nursery ground for the many animals that lived in them (herons, fish, crab, and shrimp), and that they were a form of coastal protection for local houses. However, one year when we arrived to our usual site, the mangroves were replaced by shiny new shrimp farms. Mangroves are considered suitable for shrimp farms as mangroves are planted in brackish, stagnant water which is ideal for shrimp farms (Barbier, 2004). The locals came to explain that while they were sorry that their backyard mangroves were gone, they were happy for a new prospective source of income. Coming back to the same area a few years later, the local mood had drastically changed, they desperately wanted their mangroves back. Since the mangroves provided a form of coastal protection, without them their houses were vulnerable to coastal flooding and storm surges. Many complained about having flooding problems during the rainy season, something they never experienced before starting to farm shrimp. Water from the shrimp ponds that contained shrimp effluent also leaked into the surrounding areas, contaminating groundwater, and making the surrounding soil infertile. Even rice, the backbone crop of Thailand, could not grow in the area. Locals lamented that the first few years of having the shrimp farm was profitable, however with the number of shrimp farms increasing in Thailand and globally, there was an oversupply of shrimp, decreasing the economic value of shrimp, leaving locals with less profit every year (Miao, 2016).

When I moved to the United States three years ago, I found a nation that loved shrimp as much as I do. Americans love shrimp so much that the nation dedicated an entire day to celebrate shrimp (National Shrimp Day is on May 10th - who knew?!), and there is a successful national restaurant chain dedicating their entire menu to different variations of shrimp, Bubba Gump. In 2000, shrimp became one of the most consumed seafood species, exceeding canned tuna, and is now the most consumed seafood in the United States. Shrimp consumption increased from 2.2lb/capita in 1990 to 4.4lb/capita in 2017 (Shamshak, 2019). To keep up with demand, global shrimp production has increased by an average of 10percent since the year 2000 and has yet to slow down. This is compared to poultry, which grew four percent annually over the same period (Botteman, 2019). The increase in shrimp consumption was most likely due to the increase in shrimp supply as shrimp imports to the United States surged, with shrimp imports dominating 92 percent of the United States's shrimp supply in 2017. The US doesn't seem to care where that it is importing are from, and imported shrimp dominated the US marketplace, with a 92 percent market share coming from poorly regulated countries such as Bangladesh and China (NOAA, 2018). The United States shrimp imports increased 43percent from 1999 to 2012, where shrimp imports were valued at $4.5 billion. However, in 2012, Thai shrimp farms were hit with EMS (Early Mortality Syndrome) disease, dramatically decreasing shrimp supply, and cutting shrimp exports in half. Thailand has never fully recovered, and in 2017 fell to the 8th country which exports the most shrimp to the US (NOAA, 2018). The fall in yield due to the outbreak of disease and the increasing resistance of bacterial strains against antibiotics in shrimp farms have forced the industry into more responsible intensification. However, in 2019 Thailand reamins among the world's top ten providers of both freshwater farmed shrimp ($694.3 million amounting to 4percent of global supply) and seawater shrimp ($22.8 million amounting to 1.3percent of global supply). On average, Thailand's shrimp production stands around 500,000 to 600,000 metric tons per year (Tapanya, 2015).

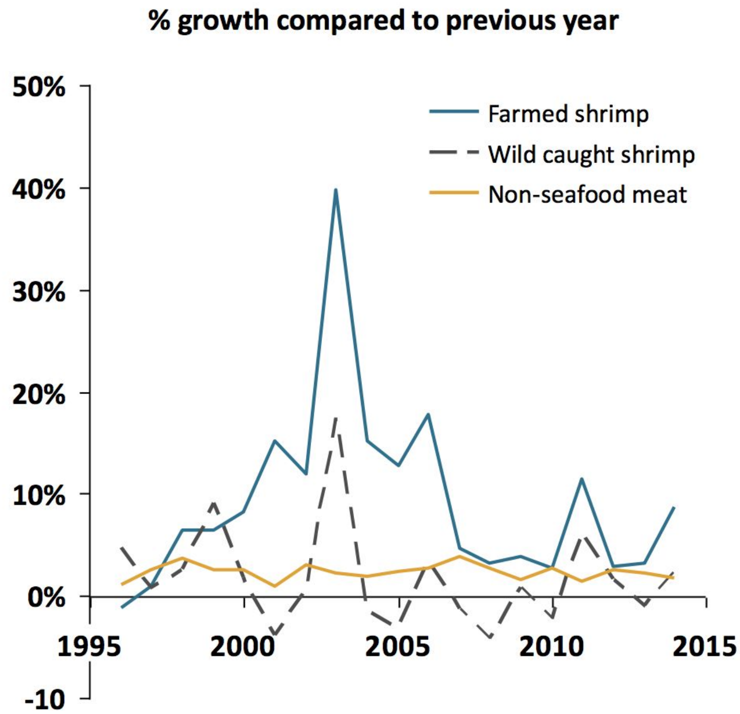

Figure 4: Global Shrimp Growth (Bottema, 2019)

Farmed shrimp accounts for 55 percent of the shrimp that is produced in Thailand, and that is the type of shrimp that this thesis will be focusing on due to farmed shrimp's environmental and social effect in Thailand. As figure 4 highlights, farmed shrimp supplies more shrimp globally than wild caught shrimp does, and growth does not seem to be slowing down. The growth mostly has been due to the rapid intensification of whiteleg shrimp (*Litopenaeus vannamei)* production, and in 2015 *L. vannamei* accounted for 80percent of farmed shrimp globally (Botteman, 2019). Black tiger shrimp (*Panaeus monodon)* production has remained stable, but relative share to global shrimp production has decreased, and in 2015 *P. monodon* only accounted for 14 percent of farmed shrimp globally. These two species of shrimp are the most popular for farmed shrimp, and the two species combined accounted for 94 percent of global farmed shrimp in 2014 (Bottema, 2019).

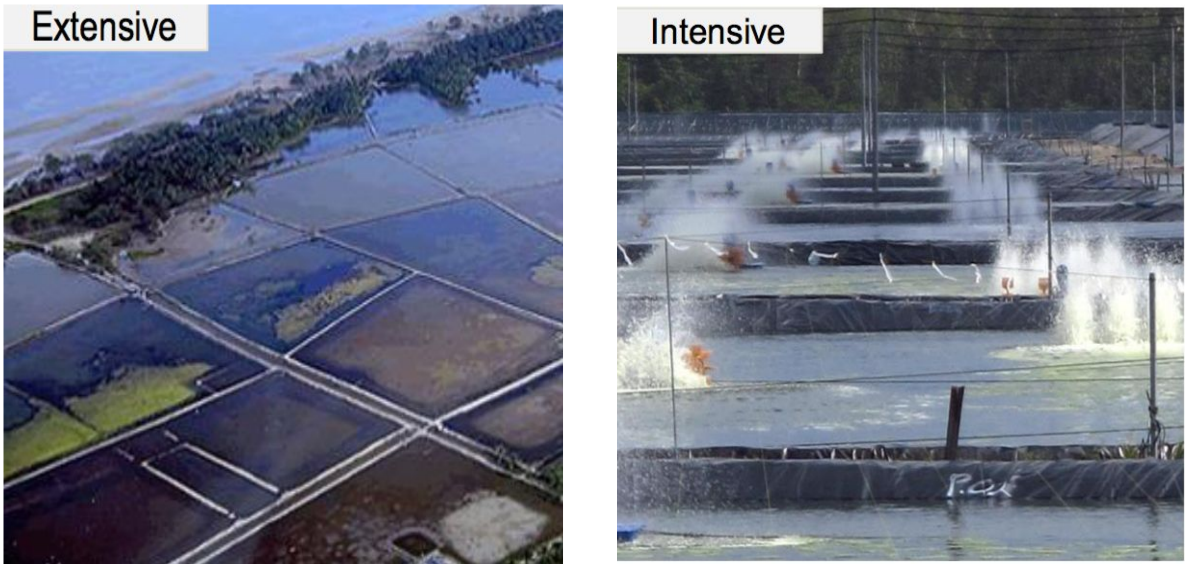

Figure 5: Visual representation of Intensive and Extensive farms (Lebel, 2012)

Shrimp farms in Thailand also have been heavily intensified in the last few decades. Intensification of shrimp farming refers to stocking density of shrimp ponds with post-larvae (adult) shrimp. With higher densities, yields per hectare of shrimp production will increase as long as shrimp survival rates are constant in the outgrowing period (Bottema, 2019). The majority of shrimp farms in Thailand currently are high-input intensive farms. These farms rely on inputs made off farms, such as high quality feed, seed, aeration, broodstock, and fertilizers. Intensive farms are packed together, and have high densities, leading to incredibly high yields such as 20-200 tonnes ha-1yr-1. The other alternative is extensive farming, which have low operating costs, relies on the natural productivity of the environment, and crop wastes as feed. This type of farming leads to lower shrimp yields, and yields >1 ha-1yr-1. Figure 5 illustrates the difference between the two types of farms. *P.monodon* rely on extensive farming while *L. vannamei* thrive in intensive farms and can be reared in higher densities than *P.monodon*, leading many countries, including Thailand, to switch to intensive farming due to *P.vannamei's* ability to thrive in high stocking densities, which generates a higher profit (Lebel, 2012).

However, shrimp caught in the oceans has its own deficits, from forced slave labor on boats, where "workers were trapped in jobs they couldn't leave, suffered from physical abuse, lack of food, long hours, and awful working conditions" (Kelly, 2018). Trawling for shrimp can heavily damage coral reefs and catch unnecessary species (Kelly, 2018). The situation became so dire and the increased "killings, beatings, and trafficking of migrant fishers many from Burma and Cambodia" that the European Commission issued a yellow card warning to Thailand, indicating that it was a non-cooperating country in fighting illegal, unreported, and unregulated fishing (Murphy, 2019). The yellow card was lifted in January 2019 (Murphy, 2019), signifying that the Thai shrimp industry leaders were ready to commit to sustainability in fishing for shrimp. Furthermore, for 2018, shrimp production was 180,000 tonnes worth 50-55 billion baht ($1.60-1.80 billion). For 2019, projects for shrimp production was 310,000-320,000 tonnes, worth 60 billion baht ($1.96 billion), a projected increase (Bangkok Post, 2018). While this accounts for farmed and caught shrimp, the data signifies that Thailand appears to be ready to embrace legal and sustainable shrimp fishing and farming.

There is yet to be a universal definition for shrimp sustainability. During an Aquaculture Industry conference in 1996, it was decided that sustainability depended not on the level of intensity, but on the quality of the site, the management, and the suitability of technology to both site and management. Sustainability included the "sustainability (or continuity) of supply, and quality of inputs, the social, environmental and economic costs of providing the inputs, the long term continuity (or sustainability) of production, financial viability, social impact, environmental impact, and the efficiency of conversion of resources into a useful product" (Aquafind, 2019). In 2018, a new initiative was launched to help improve global shrimp production and sustainability. The initiative was called the Sustainable Shrimp Partnership and members are "committed to achieving and promoting the highest quality products, produced to the highest social and environmental standards, through greater collaboration and transparency…through using zero antibiotics, fully traceable process, and a minimal environmental impact" (Fletcher, 2018).

The goal of this thesis is to find out if Thailand is able to maintain their current shrimp supply with alternative methods of raising shrimp that do little-to-no damage to the environment, ecosystems, and labor, and without compromising economic growth. This thesis takes a critical look at the challenges of attaining and maintaining sustainability in the shrimp farming industry. It will begin with the history of global shrimp aquaculture in conjunction with the development of shrimp farming in Thailand.

Then the thesis will consider the social effects of shrimp farms, how the shrimp farms have changed farmers' income, and the forced and slave labor associated with shrimp farms, especially in their peeling sheds. It will then consider the environmental destruction that shrimp farming has brought, including salinization, effect on groundwater, the use of antibiotics, effluent pollution, and the environmental effects associated with the deforestation of mangroves. Then it will consider Thai Union, Thailand's largest seafood exporter, as a case study for sustainability. It will then conclude with a set of proposed solutions for the future of shrimp farms in Thailand. Solutions include sustainability certifications, advancements in technology, closed system aquaculture, and vertical integration.

My aspiration for this thesis is not to demonize shrimp, but to convince readers that the way to move forward for Thailand must be through sustainability. Not only is shrimp farming in Thailand becoming less economically feasible and profitable, it is also associated with mangrove destruction, water pollution, and illegal labor practices (Spalding, 2018). Only through acknowledging the destructive and damaging effects that current shrimp farming has generated, can solutions be found. My thesis will attempt to answer the question whether if shrimp farms in Thailand retain high levels of shrimp production while maintaining sustainability. There is no easy solution, nor is it possible to simply outlaw shrimp aquaculture as shrimp farms still provide a major source of income for farmers. However, there are solutions where shrimp farming can and must coexist with the surrounding environment, in Thailand and the world.

Chapter 2: The History of Shrimp Farming

While shrimp domestication has been around for centuries, it started out accidentally. Shrimp farming started in Asia where wild shrimp (Penaeid shrimp) from the oceans swam into tidal impoundments inland that was intended for domesticated fish such as milk-fish, mullet fish, and other coastal finfish. (Halwart and Gupta, 2004). This method requires no inputs except for trapping and harvesting the shrimp. There were some technical developments such as trapping the shrimp during the dry season (as sometimes the ocean water would not reach tidal impoundments) by using dykes, small amounts of shrimp were harvested. The lack of advancement was mostly due to the absence of knowledge concerning the lifecycle of the Penaeid shrimp, and why they did not seem to last a full year in the coastal impoundments. However, in the twentieth century, this situation changed.

Shrimp farming in Thailand started around 1930s, where farmers relied on extensive farming methods. Farmers relied on the naturally occurring tidal flow for wild shrimp supply and naturally occuring food organisms such as plankton. Farmers would trap shrimp larvae and mature adult shrimp in tidally flooded low lying coastal areas. Most shrimp species that were trapped were the banana shrimp (Penaeus merguiensis), the school shrimp (Metapenaeus ensues) and the black tiger prawn (P.monodon) (Dierberg and Woraphan, 1996). Farmers were not putting any inputs in the farm, yield was low, and was approximately around 200 kg/ha/yr. Shrimp farms started to expand in 1947 when salt farmers received low prices for their salt, and decided to transform their salt farms into shrimp farms, and more than 50 percent of salt farms in the upper

Gulf of Thailand had been converted to shrimp ponds by 1960 (Csvas, 1994). Farmers still continued to rely on wild shrimp (most were P.merguiensis and M.ensues), nutrients, and food in sea water. Sea water was trapped during high tide in a 8-16 ha enclosure with high dikes and a sluice gate, and a daily tidal water exchange of 5-10 percent. Shrimp were harvested twice a year. Once during November-February, where there was less rain, lower salinity and higher outputs. The second harvest was during June-October, high rains and harvest was low due to lower salinity levels (Panu, 1995). Most farms were located in the Inner Gulf of Thailand, in the provinces of Samut Songkram, Samut Sakorn, Samut Prakarn, Chanthaburi, and Rayong. These farms were still using an extensive polyculture method which used wild organisms in the pond as feed (Banchong, 1970). As Thailand possesses over 2700km of coastline and has an ideal tropical climate perfect for shrimp farming, this propelled Thailand into becoming a global leader of shrimp. Furthermore Thailand has access to "aquaculture technologies, low agricultural wages and the availability of government tax incentives" were all vital in developing shrimp farming in Thailand (Kongkeo, 1995).

In 1934, Dr Motosaku Fujinaga in Japan spawned a subspecies of the Penaeid shrimp, the *Penaeus japonicus,* shown in figure 6. He was able to hatch the eggs and successfully reared the larvae to its adult stage, which was completely revolutionary at the time. While World War II halted experiments, after the war Dr. Fujinaga was able to develop the essential techniques that are still used for the basis of shrimp rearing in farms today - shrimp spawning, larval rearing, and shrimp growing (Chamberlain, 2010). Through studying hatchery and the seasonal spawning behavior of the

P.japonicus Doctor Fujinaga determined the optimal rearing temperature for breeding larvae. He also found that *P. japonicus* required different feed during the different stages of life, brine shrimp was needed during early postlarval stages, and short necked clam meat was needed for late postlarvae (Imai, 1971). Through these advancements, Fujinaga was able to increase the quantity of post-larval shrimp. He also recognized the need for pond preparation, and in 1963 started the removal of shrimp waste and sludge through draining, drying, and tiling; the first acknowledgment of the potential harmful effects of intensive shrimp farms (Chamberlain, 2010).

Figure 6: *P.japonicus* (fishgourmet, 2018)

While most research was being done in Japan, shrimp farming was destined to move to destinations with more favorable climate and greater availability of land. A Taiwanese researcher named I. Chiu Liao spent decades researching with Dr. Fujinaga during his postdoctoral fellowship, and returned to Taiwan in 1968 where he created the Tungkang Marine laboratory. This research institute became the hotbed for shrimp farming research in Asia. He was able to use the techniques used for spawning and larval rearing the *P.japonicus* for a species that was native to Taiwan, the *P. monodon,* the black tiger shrimp. Through comparing growth of six species of shrimp, *P. monodon P. stylirostris, P. penicillatus, P. japonicus, P. semisulcatus, and Metapenaeus sp*. The *P. monodon* was found to have had the fastest growth, it performed well in commercial ponds, tolerated a wide range of salinity and temperature, and it accepted formulated feed. All of this led to the rapid adoption of the *P. monodon* not only in Taiwan but also the rest of Asia. In 1974, the *P.monodon* was successfully breeded in small ponds with a high stocking density in Phuket, leading other provinces in Thailand to adopt the *P.monodon* (Chanratchakool, 2002).

When Dr. Liao began at Tungkuang in 1971, Taiwan's annual shrimp production was 427 mt, and when he left the center in 1987, production had risen to 88,264 mt, the highest in the world at that time. Liao also began researching shrimp biology, physiology, nutrition, disease, ecology, and started to heavily advocate for global use of intensive shrimp ponds (Liao, 1969). While Taiwan was researching the *P.monodon,* scientists in the United States were also researching growth rate, largest harvest size, docility, and maturation in *Penaeus duorarum, P. aztecus, P. setiferus, P. schmitti, P. brasiliensis, P. occidentalis, P. stylirostris, P. vannamei, P. californiensis, and P. paulensis*. While the *P. stylirostris* had the fastest growth, during the mid-1970s farms were hit with the infectious hypodermal & hematopoietic necrosis virus that was introduced from the Philippines, leading to high mortality. However, the one species of those tested that were not affected were the *P.vannamei*, and thus lead to the dominance of *P.vannamei* (pacific white shrimp) in the United State's shrimp farm ponds and the Western hemisphere (Chamberlain, 2010). A picture of both the *P.monodon* and the *P.vannamei* is shown in figure 7.

Figure 7: Left, *P.monodon* (Black Tiger Shrimp) (Aquaculture, 2017). Right: *P.vannamei* (Pacific White Shrimp)

Prior to the 1970s, shrimp farmers relied on fresh food such as clams and fish to feed shrimp. However, in the early 1970s Japanese researchers in Kagoshima created a purified diet with casein, fish oil, soy lecithin, cholesterol, carbohydrates, chitin glucosamine, succinic acid, citric acid, minerals, vitamins, cellulose, and lipids. These ingredients became the backbone for what shrimp feed is today. Liao further developed this formula and introduced in the first formulated feed in 1977. Farmers quickly adopted to Liao's feed and trash fish (trash fish is a mixture of organisms including shrimp and other crustaceans) became the common diet of most shrimp in shrimp farms. By 1985, manufacturers in Taiwan were producing 50,000 mt of feed in Taiwan. (Deshimaru and Kuroki 1974). The 1970's had three types of shrimp farms: extensive farms, semi-intensive farms, and intensive farms. A visual representation of an extensive and intensive farm can be seen in figure 5, and a representation of a semi-intensive farm can be found in figure 8.

Most farmers at the time had extensive farms, which relied on low inputs, limited technology, and had densities of 2-5/m^2. Ponds were coastal impoundments or mangrove intertidal areas enclosed by dykes. Ponds were large and larvae came from an exchange with tidal water from the oceans, or shrimp were manually caught at estuaries and released in ponds. Polyculture was encouraged and there were naturally stocked crab, shrimp, and fish in the ponds. The shrimp were fed with natural foods found in the coastal impoundments such as plankton, small fish, and decomposing organic matter. Animal manure was substituted as a form of organic fertilizer, and was added to increase food production. Farmers did not have much to manage, and shrimp yields were low and did not increase over 400 kg of shrimp/ha/year (Paez Ozuna, 2005).

Semi-intensive farms have small drainable ponds with an area of 1-20 ha and densities of 8-20/m^2. Existing vegetation was often cleared to make way for the ponds and inputs included treating pond bottoms with lime or tidal flushing before filling for optimal soil conditions and to kill leftover fish. Shrimp was caught either in the wild or were hatchery reared. Shrimp were fed with formulaic feed twice a day and water inside the pond is exchanged at rates of 2-20percent a day to manage dissolved oxygen and plankton density. Yields in shrimp production in semi-intensive ponds could range from 1000-2000 kg/ha per cycle, and there are two cycles per year (Teicheret Coddington, 2000).

Intensive ponds were small and were cleared of all natural vegetation. Ponds utilized 0.1-1.0 ha and could be stocked at densities of 30-60/m^2. While all the techniques used in semi-intensive farming were used, such as water exchange and management methods, in intensive farms feed is given 3-5 times a day. Juvenile shrimp were artificially stocked in the ponds. With a larger quantity of shrimp, more expensive and nutritionally dense feed was required to compensate for natural foods. Farms consisted of 0.3-0.5 ha ponds with a depth of 1.5-1.8m, and mechanical aeration is installed to manage oxygen levels. Ponds relied on high rates of water exchange as ponds are stacked next to each other. Water exchange maintains water quality, regulate plankton density, and introduces supplemental food organisms. However, there were also risks of water exchange such as pumping costs and there are detrimental environmental impacts due to the eutrophication of the pond receiving the water (Boyd, 1992). Yields are the highest in intensive farming, with yields ranging from 3000-10,000 kg/ha/cycle, with two cycles per year (Chamberlain, 2010).

Figure 8: Semi-Intensive Shrimp Farm (Assifish, 2019)

Back in Taiwan, land prices started to increase during the late 1970s due to the success of shrimp farming. This lead Liao and his team to research increasing shrimp stocking densities and productivity per unit area (Chamberlain, 2010). Due to high land costs and lower cost of production, family farms excelled over company farms. By the mid 1980s Taiwan's intensive farm method had become the model of shrimp farms throughout Asia. In 1987, Taiwan had 10,000 ha of family-owned intensive farms that produced 115,000 mt of *P. monodon* (Chamberlain, 2010).

However, the success of shrimp farming in Taiwan and other countries did not last due to the vulnerability of shrimp to disease. The first shrimp virus was reported in 1974, baculovirus penaei (BP), and the virus temporarily devastated the shrimp industry in Panama and Ecuador. Since 1974, thirty new shrimp diseases have been found, averaging one virus per year. Figure 9 demonstrates the most common diseases found in shrimp as of 2017.

Disease	*Acronym*	*Virus or bacteria*
Taura syndrome	TSV	RNA virus
White spot disease	WSSV/WSV	DNA virus
Yellowhead disease	YHV/GAV	RNA virus
Infectious hypodermal & hematopoietic necrosis	IHHNV	DNA virus
Infectious myonecrosis	IMNV	RNA virus
Necrotizing hepatopancreatitis	NHP	Bacteria (Under study)

Figure 9: Most common shrimp diseases in 2017 (Flegel, 2017)

Disease was spread as farmers shipped live larvae from one region to another without any quarantine protection. However, the disease was more commonly spread from surrounding farms. Intensive and semi-intensive ponds relied on daily water exchange, repumping each other's waste water. This decreased water quality, increased stress, and rapidly transmitted disease between farms. Some farmers also used trash fish as a supplement to pelleted feed. Farmed shrimp often became sick after eating the diseased shrimp found in the trash fish. Shrimp are animals that lack antigens and antibodies, and are easily affected by disease. Vaccination against disease was not possible, and while antibiotics can treat bacterial disease, there was no cure for viruses. Farmers also lacked the tools to properly dispose of infected shrimp, and the improper movement of infected shrimp can infect other healthy shrimp. Movements of vehicle, equipment, and personnel between plants and hatcheries without disinfection can also lead to infection (Chamberlain, 2010).

Although Taiwan was the world leader in shrimp farming in the 1980's, tragedy soon struck. The prized shrimp, *P.monodon* was mysteriously hit with 11 diseases, and no remedies were found. While the causes of the disease were attributed to pollution, bacterial diseases, and viral diseases, no official cause was ever found. In 1987, shrimp production was 115,000 mt and dipped to 44,000 mt in 1988. By 1994 shrimp production had dropped to 25,000 mt, most farmers abandoned shrimp farms for marine fish farms, and Taiwan has not yet regained its role as a global leader in the shrimp industry (Chiang and Liao, 1995).

With Taiwan leaving a gap in global shrimp supply, the Thai government saw an opportunity to replace Taiwan as the global leader in shrimp supply. The Thai government and the Asian Development Bank gave technical, financial, and infrastructural support by making shrimp farming tax free (Flaherty and Karnjanakesorn, 1995). The Asian Development Bank also approved a US $11.1 million loan in 1986 for a brackish water shrimp culture development project, along with the government encouraging the farming of the P.monodon for it's fast growth. These developments pushed Thailand into the forefront of global shrimp production (Gronski and Heffernan, 1996).

With the monetary support of the Asian Development Bank, the Thai government heavily advocated for the advancement of shrimp farming. In 1987, semi-intensive shrimp farming began in Thailand. Governments persuaded extensive farms to switch to intensive farms with promises of higher yields and profits. *P.monodon* were harvested and stocking densities ranged from 20PL/m2 - 40 PL/m^2. Flow through systems were used to maintain water quality and increase shrimp growth. Flow through systems are systems where "the fish are stocked densely in a long and narrow pond or tank in which there is an abundant continuous water flow. The fish are stocked in these ponds or tanks on the basis of the volume of inflowing water. They are fed a formulated pelleted food and usually this is their only source of nutrition. A continuous water flow ensures the proper oxygen supply to the fish and flushes away the metabolic wastes" (Kepenyes, 1983). The system also maintained good pond water quality and accelerated shrimp growth. A diet of supplements were also used in the form of dry/wet feed, and daily water exchange was introduced. Through this system farmers harvested shrimp twice per year, and yield was 4000-10,000 kg/ha/yr. National shrimp farm production increased from 23,566 tons in 1987 to 263,500 in 1994 (Dierberg and Woraphan, 1996).

However, even Thailand was not immune to disease. In 1992-1993 farmers nationwide started to report that shrimp were dying in 3-5 days once they were infected with a mysterious disease. One of the symptoms was a light yellow swollen cephalothorax (the head of the shrimp) a picture of shrimp with YHV is shown in figure 15. The disease was aptly named the yellow head virus (YHV) and it caused shrimp growth to slow down by 32 percent between 1990-1991. Researchers were able to identify the pathogen as a cytoplasmic RNA virus spread through small brackish water shrimp, the *Palaemon styliferus* which often inhabit shrimp ponds. YHV was also found to be active in seawater for 72 hours once the infected host shrimp has contaminated the water with its waste.

Figure 15: Shrimp with YHV (Ganjoor, 2015)

The identification of the pathogen lead the Thai Department of Fisheries to educate farmers on how to contain the disease. The department urger farmers to replace flow through systems with semi-closed intensive shrimp farming systems with semi-closed intensive farms. Instructions also included not using trash fish as feed, installing filters on water systems between ponds to prevent small shrimp from entering, and warning neighboring farms of infection by not pumping for 72 hours once the infected pond was drained. The success of this education program decreased YHV outbreaks. (Chamberlain, 2010).

While these instructions were critical in the containment of the disease, the main culprit of the disease was found to be the poor water quality in the Inner Gulf of Thailand. The gulf receives urban, industrial, and agricultural waste from Thailand's major river systems, including the Chao Phraya River (where Bangkok's waste is deposited), and the Mae Klong (which carries waste water from sugar factories in Western Thailand). The disease and contamination left 45,000 ha of farms abandoned (Briggs, 1994). However, Thailand was able to maintain its status as a global leader in shrimp production. This was achieved through the migration of shrimp farms to the northern gulf regions, the east, and the south. Migration and the steady improvement of farming methods enabled Thailand to respond to global shrimp demand.

While the mysterious disease that crippled Taiwan's shrimp industry was contained in Taiwan, another disease in the 1990s was identified, spread globally, and destroyed global shrimp populations. This disease was known as white spot syndrome virus (WSSV); as the main visible symptoms of the disease were 1-mm white spots on the cuticle of the infected shrimp, as illustrated in figure 10. This disease was first observed in China, and affected shrimp in all types of farms (extensive, semi-intensive, and intensive), and could affect all stocking densities ranging from $4/m^2$-$25/m^2$ (Rosenberry, 1994). In 1995, the virus had spread from China through Asia. However, four years later the disease was observed in Ecuador, and was transmitted by the processing of plant waste containing infectious viral material from frozen Asian shrimp processed in South America (Lightner, 2001). It was further spread through the disease prevalence in the gut and faeces of aquatic insects such as the water boatman and gulls, animals that lived near and deposited waste in shrimp farms (Vanpatten, 2004). The disease caused mortality rates of 60-90percent in *P.vannamei* shrimp, which is native to Ecuador and the main species of farmed shrimp in Ecuador. WSSV seriously affected shrimp supply, and it was estimated that 60percent of the total shrimp disease losses of $1 billion in 2001 was due to WSSV (Flegel, 2006).

Figure 10: Shrimp with White Spot Syndrome Virus (WSSV) (Rahman, 2018)

Disease in many shrimp farms around the world caused global media to pay attention to the detrimental labor and environmental effects of shrimp farming. The verdict was that shrimp farming needed to be stopped immediately due to the social and environmental effects were just not worth the high yields of shrimp. In 1998, an article in *Science Magazine* stated that "Crop failures appear to result largely from poor environmental management of shrimp farms.... When shrimp yields decline, ponds are often abandoned; the life span of intensive shrimp ponds in Asia rarely exceeds five to 10 years" (Naylor, 1998). In the same year Greenpeace pointed out that shrimp farming was

"...an unsustainable industry, migrating from place to place, leaving behind a trail of degraded landscapes stripped of biodiversity, and destitute people" (http://www.greenpeace.org/politics/wto/shrimp.html). Environmentalists also critiqued shrimp farming, as they were concerned about the discharge of effluents into the surrounding area, deforestation, and subsequent replacement of mangroves for shrimp farms. Research in 1997 found that 5 percent of the world's mangroves had been deforested for shrimp farms (Boyd, 1999). However, farmers defended themselves and their businesses. For example farmers in Ecuador had shrimp ponds that were built forty years ago that were still in operation and were still sustainable (Laniado, 1998).

In 1997, the Global Aquaculture Alliance (GAA) was established to help create a sustainable future to the aquaculture industry. The first step was creating management practices titled "Codes of Practice for Responsible Shrimp Farming" (Boyd, 1999). The rules mostly concerned sustainability in the shrimp farming industry. The GAA forced farmers to evaluate the extensive pond techniques that most farmers were using. Extensive ponds relied on wild shrimp, clean estuarine water, and a surrounding ecosystem to release waste. However, it pointed out that wild shrimp could be infected with diseases, estuarine water could also contain disease and disease carriers, and nutrient discharge can ruin the surrounding environment. The GAA introduced new technology to "diagnose diseases, develop specific pathogen free stocks, breed for disease resistance, disinfect and reuse pond water, improve feed efficiency, and predict the carrying capacity of ecosystems" (Chamberlain, 2010).

Disease was identified through techniques such as polymerase chain reaction (PCR) in the mid 1990's, as PCR could detect pathogens through finding minute quantities of specific viruses by amplifying pieces of extracted infected DNA/RNA by thousands of times. In the late 1990s and 2000s it became common for farm managers to ask for PCR testing on larvae from hatcheries to see if it contained WWSV before stocking ponds with the batch. However, due to the cost and time associated with the practice, it was impractical for multiple testing over time (Van Patten, 2006).

Another way farms prevented disease was through selecting strains of shrimp that were disease immune to a specified list of pathogens (SPF). However, in 1993, SPF *P.vannamei* stocked in Ecuador proved to be fruitless, as the shrimp were hit with the Taura syndrome virus (TSV), leaving survival averages to be less than 15percent and left Latin America farmers with a distaste for SPF shrimp that was never overcome (Wyban, 2007). This proved that SPF shrimp were not suitable for farms that were unable to control entry of pathogens, as farms in Ecuador were mostly large extensive/semi-intensive ponds(Pruder, 1995). At this point shrimp farming in the Americas were using *P.vannamei* and Asia were using *P.monodon*. Most farms still heavily relied on wild shrimp, and shrimp farm production had reached a "carrying capacity" for wild shrimp. While farmers tried to use a higher quantity of shrimp to increase yields and profits, wild shrimp often carried diseases and weren't suited to intensive ponds (Wyban, 2007).

In the late 1990s SPF shrimp was introduced to Asia, and did incredibly well, as SPF were suited to small, aerated intensive ponds that were plentiful in the region. This was demonstrated in 1996 when SPF *P.vannamei* were introduced into Taiwan where trials yielded 12 mt/ha of 12-15 g of shrimp in 75 days (Wyban, 2002). SPF *P.vannamei* virtually replaced *P.monodon* as at the time *P.monodon* in Asia were suffering through WSSV through wild shrimp as most pond were still extensive/semi-intensive ponds. The rest of Asia, particularly South East Asia, rapidly adopted the *P.vannamei.*

This was due to the several advantages that *P.vannamei* had over the *P.monodon*. The *P.vannamei's* nutritional requirements are also less expensive. Inexpensive protein feed can be used with *P.vannamei* and it can also eat pond generated food. Secondly, the *P.vannamei* can be stocked in higher densities, and *P.vannamei* can be stocked at densities over 500PL/m^2 (Samocha, 2010) and thus were well suited to intensive ponds. World shrimp farming of *P.vannamei* increased from 10percent of total production in 1998 to 75 percent of world production in 2006 (Wyban, 2007).

With the intensification and domestication of *P.vannamei,* farms also started to improve their production processes to reduce the risk of disease. Farms in Asia, while still remaining intensive and increasing stocking densities, stopped or reduced water exchange with each other to reduce the risk of disease transmission, increased aeration to allow more oxygen to flow into the ponds to increase circulation and reduces disease, and ponds were lined ponds with plastic liners to reduce erosion. (McIntosh and Avnimelech 2006). The globalized domestication (especially in Asia) of *P.vannamei* lead to the rapid expansion of the global shrimp industry. In 2000 global *P.vannamei* accounted for only 10percent of total global shrimp production. Ten years later it soared to 80 percent. In 1996, shrimp production was worth $3.5 billion and in 2010 it was worth $13.3 billion (FAO, 2010).

In 2001 in Thailand, the main shrimp that was farmed was the *P.monodon* and annual yield peaked at 280,000 MT. However, in the same year another disease called Monodon Slow Growth Syndrome (MSGS) lead to slow growth in shrimp, smaller harvest, and thus lower prices. As researchers were unable to figure out the cause of the disease, farmers started to become resigned about the frequent sporadic diseases in the *P.monodon*. With the success of *P.vannamei* in Taiwan in 1996, Thai farmers were ready for a new species of shrimp that could grow quickly and was resistant to disease. Limited quantities of *P.vannamei* were shipped to Thailand in 2001, and the stock was found to be consistent with production, had high survival and fast growth rates. An added bonus, the *P.vannamei* were also more tolerant to high stocking densities than the *P.monodon*. More samples were sent in 2002, and by 2006 *P.vannamei* represented over 98percent of total national shrimp production, figure 11 illustrates the change from *P.monodon* (black tiger shrimp) to *P.vannamei* (pacific white shrimp). Figure 12 also shows the superiority of the *P.monodon* over the *P.vannamei* in terms of stocking density and profit, with *P.vannamei's* profit proving to be 2-3 times greater than the *P.monodon (Wyban, 2016)*.

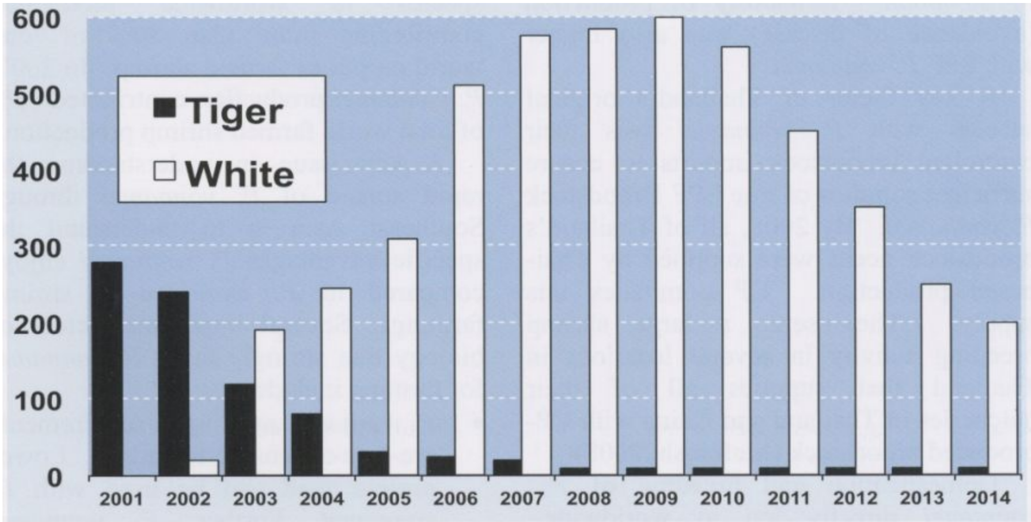

Figure 11: Thailand's annual shrimp farming production by species (Wyban, 2016)

Parameter	*P. monodon*	*P. vannamei*	Difference
Density (PL/m^2)	40-50	120-200	300%
Crop duration (days)	110-140	105-120	27%
Harvest size (g)	22-28	21-25	5%
Yield (mt/ha/crop)	8	24	300%
Crop value (U.S. $/ha)	$45,000	$96,000	220%
Crop costs (U.S. $/ha)	$32,000	$60,000	187%
Profit (U.S. $/ha)	$13,000	$36,000	280%

Figure 12: Production and profit of *P.vannamei* and *P.monodon* in Thailand (Wyban, 2016)

In 2008 the broodstock of *P.vannamei* were all supplied by Thai-based production. *P.vannamei* loved Thailand's climate and adapted to the intensive farms, and rapidly accelerating Thailand's shrimp supply accelerated in a year. In 2009-2010 stocking densities increased from 40 PL/m2 40 PL/m2 to 200 PL/m2 and yields increased to about 8,000 to 30,000 kg/ha/yr, and in the span of a year shrimp contributed $3 billion to the Thai economy (Boonyawiwat, 2016).

Global shrimp supply was continuously increasing (illustrated by figure 14), global shrimp production had increased by approximately one million tonnes in 2000 to four million tonnes in 2011 (Jory, 2012) until disaster struck again. Early Mortality Syndrome (EMS) also called Acute Hepatopancreatic Necrosis Disease (AHPND) was first observed in Hainan, China, in 2010 . The next year EMS was detected in Vietnam and Malaysia. Both the *P.monodon* and the *L.vannamei* are affected by the disease. EMS affects young shrimp larvae within 20-30 days after stocking and will cause death, and will cause 100 percent shrimp-and-pond mortality within a week. Symptoms include lethargy, anorexia, soft darkened shells, and mottling of the hepatopancreas (Lightner, 2012), figure 13 shows shrimp with EMS. EMS is caused by toxins found in *Vibrio parahaemolyticus* bacteria. The bacteria becomes active and virulent when it gains an AHPND plasmid that provokes cell death (Dangtip, 2015). In 2011, EMS spread to Thailand and supply started to decrease. Production dropped by more than 50 percent over a period of 3 years, from 603,227 tonnes in 2011 to 263,245 tonnes in 2014. Figure 11 illustrates the sharp drop in Thailand's shrimp supply starting in 2011 due to EMS. Exports followed, declining from its peak of 425,000 tonnes in 2010 to its lowest point of 156,000 tonnes in 2015 (Chamberlain, 2010).

Figure 13: Shrimp with EMS/AHPND (Flegel, 2012)

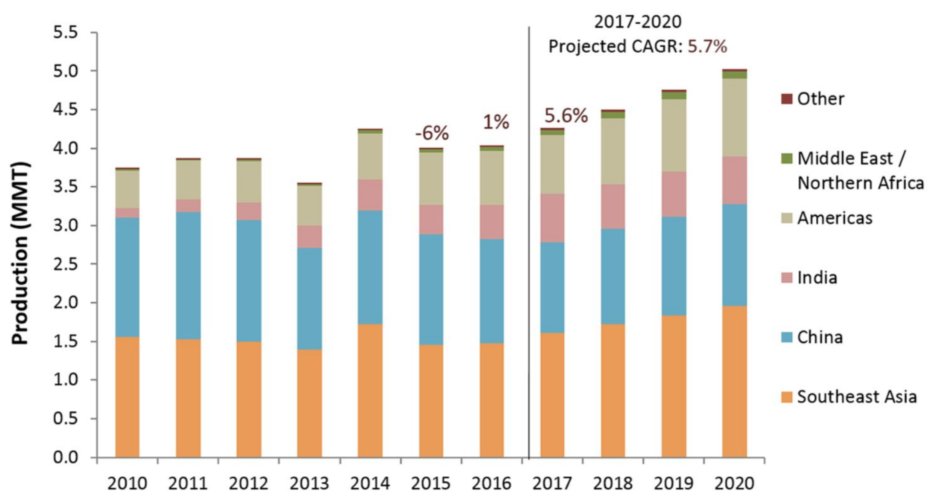

Figure 14: Shrimp farm production by region over time (FAO, 2018)

Because in 2013, the annual global losses of EMS for was $1 billion (GAA, 2013), solutions needed to be found fast. The most effective solution (except for stocking ponds with EMS free shrimp) was to apply microbial management in hatcheries to make sure that the shrimp were healthy before stocking them in the ponds (Boonyawiwat, 2017). Microbiota included algae rich green waters and microbial mature water systems. Environments primarily colonized by slow growing harmless bacteria was found to prevent later EMS outbreaks (Schryver, 2014).

However, the most innovative solution was the development of a new type of farming, called Intensive 2.0. After the disaster of the EMS outbreak, the Thai shrimp industry and farmers decided to change their production techniques. Ponds could still provide high yields of shrimp, but shrimp had lower chances of contracting diseases such as EMS. A table provided in figure 16 compares the advantages that Intensive 2.0 farms have over intensive and extensive farms. Intensive 2.0 farms concentrated on water filtration and circulation, slowing down the risk of disease. As most intensive farms exchanged waste water with each other, Intensive 2.0 farms not only reduced water exchange in aerated ponds, but also installed pond filters which helped disinfect the water and remove disease carriers (McIntosh and Avimelech, 2006). By allocating 50 percent or more of total pond area to water treatment, stopping the sharing of pond water, and separating pond water, disease became less rampant.

Intensive ponds also relied heavily on aerators, as aerators were thought to oxygenate the ponds and circulate pond water. However, aerators often increased water velocity which lead to erosion of internal levees. The levees then eroded soil which then smothered organic waste, leading to anaerobic deterioration of pond sediments. An affordable solution to pond erosion was found through the use of plastic liners. Plastic liners helped prevent erosion and lead to less tilling and drying of the soil (Smith, 1996). Figure 15 shows an image of a shrimp pond in Sam Roi Yod, Thailand, equipped with aerators and plastic liners. Aerators were also replaced by advanced filtration systems, such as central drains, which provides a clean source of oxygenated and filtered water to shrimp ponds. Systems such as central drains clear the detritus and sediment material, such as leftover feed and shrimp waste, from the bottom of the pond. By using the central drain multiple times a day to remove waste, this creates water circulation and a clean environment in ponds. Furthermore, the use of probiotics in Intensive 2.0 ponds, also helps improve shrimp health.

Figure 15: Intensive 2.0 farms in Sam Roi Yod, Thailand (Medium, 2017)

Shrimp waste in ponds is also disposed through the use of probiotics. Probiotic bacteria and microorganisms such as Bioflocs, breaks down shrimp waste, which contains ammonia and nitrite, into harmless dissolved nitrogen. Bioflocs also act as a natural food source for shrimp, further supplementing their diet. Disease is further controlled through having an external nursery. As symptoms of EMS normally show within the first 40 days, by using an external nurseries for shrimp larvae, farmers are able to monitor the larvae during its juvenile stage for signs of EMS. Once the 40 days are over, farmers are able to select post-larvae who have survived, an eventually breed a batch of shrimp which are resistant to EMS.

SHRIMP AQUACULTURE FARMING METHODS

	EXTENSIVE	INTENSIVE	INTENSIVE 2.0
STOCKING DENSITY	LOW	HIGH	HIGH
YIELD	LOW	HIGH	HIGH
MODERN TECHNOLOGY	NONE	SOME	HIGH
RISK OF DISEASE	LOW	HIGH	LOW

Rubicon® resources
Purity from Pond to Plate

Figure 16: Comparison of Extensive, and Intensive 2.0 farming (Rubicon, 2017)

Beginning in 2014, shrimp farming began to recover. Shrimp production, especially in Asia, took a noticeable dip as illustrated by figure 8, since 2014 shrimp production has been steadily increasing. Shrimp production is expected to grow by 18 percent over 2017-2020 and production and reached 4 million mt in 2018, similar to pre-EMS levels, the increase was driven primarily by Vietnam, Indonesia, and China. (Anderson, 2018).

Shrimp production in Thailand is also on the road to recovery: in 2016, it produced 314,018 tonnes of *P.vannemei*, accounting for 97 percent of farmed production, *P.monodon* production contributed to the remaining 3 percent, and exports of shrimp amounted to $1873.8 million (Ngamprasertkit, 2018). Thailand's shrimp supply is also expected to grow by 8 percent from 2015-2020. However, recovery would still only be tantamount to 57 percent of Thailand's largest production pre-EMS; as of 2019, and Thailand's supply still lags behind China, Vietnam, Indonesia, and India (Anderson, 2018).

Chapter 3: The Social and Economic Effects of Shrimp Farming

Economic value of shrimp

Shrimp can provide a large source of income for farmers. Locals in coastal areas of Thailand are primarily fishermen or agricultural laborers, and are relatively poor. Interviews with shrimp farm owners in Thailand revealed that installing a shrimp farm increased overall living standards for 90 percent in the studied villages, and 96 percent of locals claimed that they were able to make more money through shrimp farms than their previous jobs, leading to fewer people living below the poverty line (Lebel, 2002). Since shrimp is worth more money than products that are traditionally grown, such as rice, larger sums of money can be made relatively quickly. Thailand produced approximately 540,000 tonnes of shrimp in 2012 and annual sales were worth $3-4 billion dollars (Bangkok Post, 2013). While the main benefactors of shrimp sales may be the owners and thus higher class individuals, employees have also benefited from shrimp farming.

The Thai Shrimp Industry's Value Chain

The shrimp industry value chain in Thailand by gross profit margin includes 25 percent of farming and trading, 30 percent in processing, and 45 percent in retail and distribution. Smaller shrimp farms in Thailand, especially after 2012's EMS outbreak, have struggled to stay independent. Shrimp farming in Thailand and globally have started to fully integrate with other parts of the value chain, and smaller shrimp farms have started to become integrated with large shrimp integrated companies that have their own processing and marketing units, hatchery, feed mill, and grow out facilities. This guarantees that their products become standardized and are more cost effective. Furthermore, with large Thai seafood companies such as Charoen Pokphand Foods (CPF) and Thai Union Frozen (TUF) developing the capacity to breed shrimp that are pathogen free have convinced smaller farmers to consolidate (ILO, 2016).

Labor is mostly concentrated in shrimp processing, which is separated into primary and secondary processing. Primary processing includes collecting, washing, peeling, and deveining shrimp. Secondary processing adds value to shrimp, by frying, converting shrimp to sushi, and ready-to-eat shrimp. The products of most secondary processing plants are exported and have to meet certain international standards concerning the quality of shrimp and labor standards (Yupensak, 2018). Organisations such as the Best Aquaculture Practices (BAP) have a list of labor standards and qualifications that farms must meet to obtain the BAP certification (BAP, 2015) [1]. About 45 percent of the exported shrimp are sold raw with simple processing, while 40 percent are cooked, and only 15 percent undergo further processing to generate higher value added. Furthermore, 90 percent of shrimp produced and processed is exported overseas, and only 10 percent of shrimp is consumed domestically. Shrimp sorting mostly happens at sites near or at the farms, as shrimp are processed immediately after they are removed from the water. Shrimp processing companies can either be independently contracted or can be part of a large company. The lack of regulation that bind manfactorers can involve a high amount of undocumented and migrant labor in

[1] The standards and qualifications for BAP can be found here: https://www.bapcertification.org/Downloadables/pdf/standards/PI%20-%20Standard%20-%20Seafood%20Processing%20Plant%20Standards%20-%20Issue%204.2%20-%2031-December-2015.pdf

labor intensive operations. "There are currently 185 registered shrimp processing facilities in Thailand, operated by approximately 100 processors. Seventeen of these are large-scale processing sites operated by major players such as CPF, TUFPac Food, Rubicon Resources, Surapol Food, and Thai Union, while the vast majority (168 factories) are small and medium-sized facilities (ILO, 2016)

Labor and Employment in the Shrimp Industry

Underpaid and migrant workers have also been an integral part of the shrimp farming business. While this issue is rarely addressed, it must be acknowledged that a large majority of employees working in the shrimp industry in not just Thailand and globally are being exploited. The shrimp industry employs 700,000 workers, 80 percent of whom are migrant workers who largely migrate or are trafficked from Myanmar (ILO, 2016). Informant interviews also showed that one fourth of migrant workers in the shrimp industry are unregistered. Unregistered workers are often taken advantage of and are subjected to labor intensive activities such as farming, sorting shrimp, and simple processing under small contract manufacturers in simple processing plants (ILO, 2016). Due to the lack of formal regulations in simple processing, which are mostly controlled by independent contractors, workers are more likely forced into inhumane work conditions. This is compared to secondary processing housed in larger companies which are subjected to stricter legal standards from overseas buyers and are also regulated by authorities. Secondary processing workers mostly include national and documented migrants, where working standards comply with laws and regulations (ILO, 2016).

While corruption is prevalent throughout the entire shrimp industry, arrests are rare. When raids and arrests do happen, undocumented migrants end up being more harshely prosecuted than the owners. Most of the exploitation happens in shrimp sheds, where workers can be hidden in a closed space. Shrimp sheds can be hidden in plain sight, behind residential streets or behind no walls. The Thai Frozen Foods Association lists 50 registered shrimp sheds, however many unregistered sheds operate in Samut Sakhon, a coastal town and the country's main shrimp processing region (TFFA, 2015). Small sheds, the typical sized shed in Samut Sakhon,employs has 50 to 100 workers. An International Labor Organisation report found that 60 percent of migrant workers in Samut Sakhon are forced laborers, and that there were 10,000 migrant children aged 13-15 working in Samut Sakhon (ILO, 2016)

A 2015 report published by the Associated Press investigated the Gig peeling factory in Samut Sakhon, which had three sheds and each shed employed 50 to 100 people each. Many workers in the shed were found to have had no visa or work permit, and were lured to Thailand with the promises of good paying jobs. Migrants who did have work visas had their ID and passports taken by their boss, ensuring that they could not leave. The report found that in one of the sheds "seventeen children peeled alongside adults, and children never went to school and began peeling shrimp just an hour later than adults." In figure 17, children are shown sitting beside adults during the raid in the Gig factory. Salaries were calculated by how fast employees peeled shrimp, and sanitary equipment such as gloves and rubber boots were taken out of employees pay. Even with protective clothing, employees often received a “patchwork of scars from infectious allergies caused by the shrimp” and workers told reporters of “slave like conditions after being brutally beaten across his ear and throat with iron chains.” Reporters from the *Associated Press* followed trucks leaving the Gig factory and found that the trucks were entering supply chains of Thai Union, which prior to the bust “shipped 15 million pounds of frozen shrimp to dozen of U.S. companies such as Red Lobster and Darden Restaurants” (Kurtenbach, 2015).

Figure 17: Adult and Children Workers at the Gig factory (Mendoza, 2014)

The AP won a Pulitzer Prize, raising awareness of the horrific conditions inside the peeling sheds. However, critics argued that the solutions have been largely cosmetic. The workers, once freed, were taken to police custody and then "sold to agents who trafficked them again into the seafood industry" (Mason, 2015). Furthermore, no one from the Gig factory was arrested for human trafficking, but many migrant workers and their children were deported back to Myanmar or were detained on the grounds of illegally crossing the border. Although the Gig factory is now closed, many of its former workers were removed to another shed linked to the same owners (CBC, 2016).

While exploitation in peeling sheds are ubiquitous, exploitation can also happen in the sea. Many undocumented workers are hired to work on boats to fish for trash fish, infant or inedible fish, that is processed to become fishmeal for farmed shrimp. A six month investigation by the *Guardian* in 2014 found that the CP group, a company that owns the most shrimp farms in Thailand, buys fishmeal from suppliers that own fishing boats with slaves. Escaped workers from boats that supplied to CP told the *Guardian* that conditions included "20-hour shifts, regular beatings, torture and execution-style killings. Some were at sea for years; some were regularly offered methamphetamines to keep them going. Some had seen fellow slaves murdered in front of them." The CP group had an annual turnover of $32 billion in 2015 and sells its own shrimp feed to other farms, supplies to international supermarkets, food manufacturers and retailers, along with making its own cooked and ready made shrimp. The CP's group managing director in the UK, Bob Miller, admits to "not defend what is going on. We know that there's issues, we just don't have visibility." The CP group later released a statement saying that they were going to try to influence the Thai government to enforce rules and regulations on the industry, and that the CP group would use alternative proteins in the fish feed and eliminate fishmeal by 2021 (Hodal, 2014).

The European Union imposed a "yellow card" under Thailand's unregulated fishing network and threatened to ban Thai fisheries if the Thai government did not rectify the labor issues that surrounded the aquaculture industry. In response to this, the Thai government created the Sustainable Seafood Taskforce, a group that was made up of supermarkets, buyers, and retailers sourcing seafood from Thailand to bring transparency to supply chains. Both the taskforce and representatives from Thai Union persudaded the Thai government to compensate victims and witnesses of human trafficking to stay and work in Thailand for a year while their case was investigated. Whistleblowers concerning human trafficking could also be compensated $2800 in education, employment, monetary compensation, and other assistances. However, the group has failed to make much progress, and in 2015 Thailand failed to find any cases of forced labor in inspections of 474,334 fishing crew (Kelly, 2018). To tackle the lack of government regulation the Global Aquaculture Alliance also created a "Best Aquaculture Practices" certification in 2016, which is awarded to and motivate companies that move shrimp peeling in facilities that are owned and completely controlled by the processing plants (Mendoza, 2016).

Chapter 4: Case Study: Thai Union[2]

Thai Union is the largest supplier of canned tuna in the world, and also owns half of the shrimp exports out of Thailand. It is now a fully integrated company: its upstream operations includes shrimp hatcheries and farming and feed production, and its downstream operations include processing, distribution, and branding. Thai Union employed 49,000 employees and revenue in 2017 was $4.5 billion. Half of the revenue came from tuna and the other half came from such seafood businesses such as processed shrimp (Annual Report, 2018).

In 2015, Thai Union's reputation plummeted after the Associated Press article was published. In response to the article, Thai Union's CEO, Thirapong Chansiri, announced that he was "disappointed that despite our best efforts we have discovered this potential instance of illegal labor practice in our supply chain" (Mendoza, 2015). The company moved their shrimp processing in-house and opened their own peeling warehouse inside their packing and exporting factory at the end of 2015. The 1200 workers that are employed in the warehouse get subsidized meals, daily wages, and opportunities for bonuses. Thai Union also offered all the workers at the Gig factory jobs, accommodations, and food (Mendoza, 2015). A year later in 2016,the Associated Press did a follow up report on the Thai shrimp industry. The report found that Thai Union started to vertically integrate and stopped using peeling sheds from third parties (Mendoza, 2016).

[2] The head of sustainability at Thai Union, Darian MacBain, was originally supposed to be interviewed for this Thesis. However, unforeseen circumstances lead her to be unavailable for an interview. Thus, all information about Thai Union is gathered from their website and online sources concerning Thai Union.

Thai Union reviewed their supply chain to identify what areas they had to change. Within six months after the article was published, Thai Union had drafted a code of conduct and sustainability plan that governed itself and it's suppliers (Mendoza, 2016). The company became the first Thai seafood company to apply a "zero recruitment fee" policy for their workers, ensuring workers were not mislead into paying fees to recruiters. Thai Union also promised to ensure traceability of all their seafood products, and are improving on working conditions on their fishing fleet. This is done in conjunction with Greenpeace, as Thai Union signed an agreement in 2017 that would eliminate "exploitative and unsustainable practices" from its supply chain. The changes that Thai Union made after the article was published was substantial enough for them to be listed on the Dow Jones Sustainability Index Emerging Markets every year since 2015. Mr Chansiri hoped that Thai Union would be able to be on the forefront of sustainability: "Because of the effort we have made so far, I want to turn it into a positive element for the company that differentiates us from the others in the industry" (Reed, 2018).

In 2017, the company in collaboration with GreenPeace, launched their SeaChange initiative that focused on traceability and transparency, propelling Thai Union as a leader of sustainability in the global seafood industry. The goals of the initiative were to "support best practice fisheries, improve other fisheries, and reduce illegal and unethical practices in its global supply chains" (Thai Union Annual Report, 2017). In 2018, Thai Union also initiated a collaboration between the United Nation Global Compact Network in Thailand, an initiative where Thai Union focused on contributing to the UN's sustainable development goals. Figure 18 highlights methods in which Thai Union is working towards the goals. At the end of 2018, SeaChange achieved the highest ranking of the Dow Jones Sustainability Index, proving that companies can be both profitable and sustainable (Thai Union Annual Report, 2018).

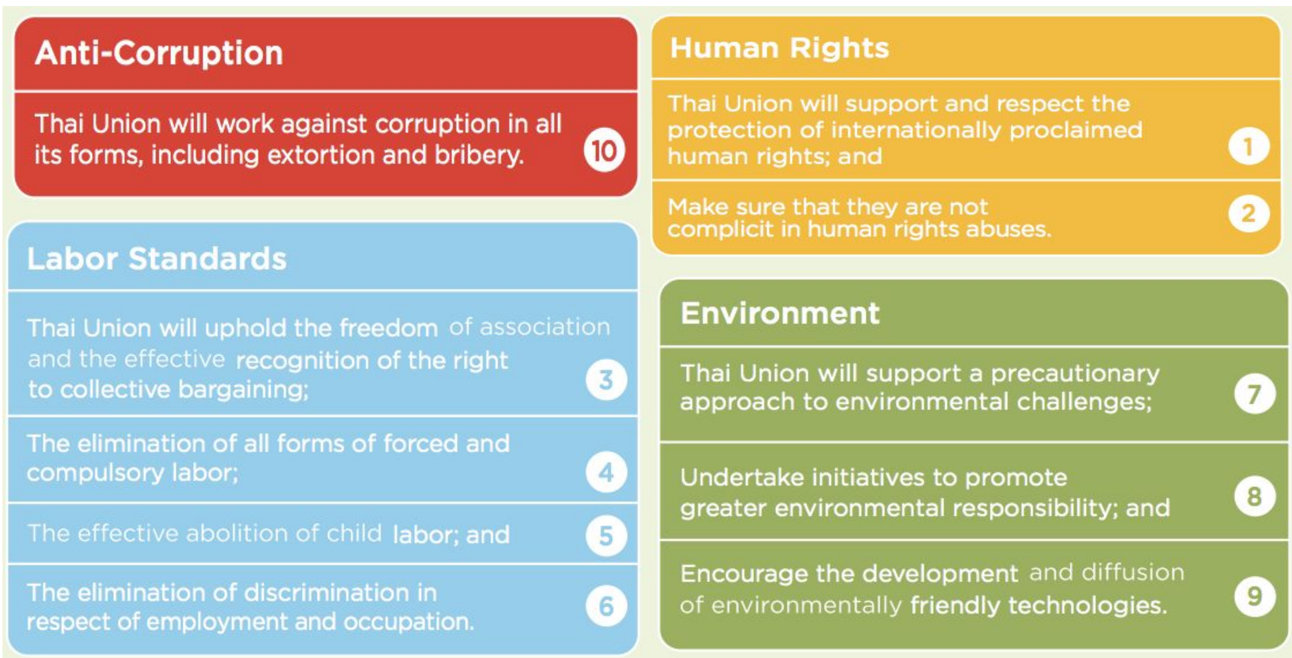

Figure 18: How Thai Union contributes towards the UN's sustainable development goals (Thai Union Annual Report, 2018)

Chapter 5: Environmental Effects

Pollution from Shrimp Waste

Intensive shrimp aquaculture requires artificial feed to meet the nutritional prerequisites and maximize shrimp growth, antibiotics to prevent disease, pesticides, and harmful chemical compounds that are needed to maintain shrimp growth. The components that are found in the discharge include solid matter (eroded pond soils), organic matter (rotting shrimp feed, dead shrimp, and shrimp feces), and dissolved metabolites (ammonia, urea, and carbon dioxide) (Boyd, 2001). Most shrimp farms dispose of the polluted water and waste products into surrounding areas and nearby waterways. Intensive systems require that 30 percent of pond water must be flushed out daily, and in 2006 Thailand shrimp farms ponds discharged 1.3 billion cubic meters of effluent (Lebel, 2009). In terms of human waste equivalents, it is estimated that 40,000 ha of intensive shrimp ponds in Thailand in 1992 produced N-waste that was equal to 3.1-3.6 million people and P-waste equal to 4.6- 7.3 million people (Briggs and Funge-Smith, 1994).

Water is exchanged in shrimp ponds by pumping water from surrounding rivers or from surrounding groundwater suppliers. The waste water is pumped from ponds into canals, rivers, and adjacent sources of water to remove unwanted nutrients, dissolved gases, and pathogens. This can lead to the contamination of water supplies and surrounding land from polluted, salinic, and often acidic water which can leach into the surrounding soils. It can also lead to coastal pollution which can decrease wild aquatic stock. A decrease in water quality can also result in subsequent disease outbreaks and a decline in shrimp farm productivity (Naylor, 2000).

Much of the salt in the water of shrimp ponds is flushed into the surrounding environment, meaning that salt can enter nearby waterways and rice paddies (Braaten and Flaherty 2001). While the impact can be subjective depending on local hydrology, salinity, soil properties, and pond management practices, soil composition change can be irreversible. This can reduce land productivity, make soil infertile, and render groundwater undrinkable (Biao. 2007).

The chemicals that are used in fish feed and organic waste may also pollute the marine environment. Due to the lack of published information concerning shrimp nutrient requirements, most feeds have an overabundance of nutrients, regardless of the shrimp stocking densities or the food available in farm systems (Tacon, 2002). Thus, a large amount of waste in shrimp ponds is accumulated in uneaten food, shrimp feces, ammonia, phosphorus, and carbon dioxide (Boyd, 1998). A report found that in intensive Thai shrimp farms, 23 percent of total pond nitrogen input and 12 percent of total phosphorus were incorporated into shrimp biomass. 22 percent and 7 percent were released from the pond through routine water exchange (Briggs, 1994). Uneaten feed can accumulated at the bottom of the pond, potentially leading to disease. Ponds that are high in organic matter can also lead to high biological oxygen demand (BOD), leading to oxygen depletion in waters that receive shrimp pond effluent, affecting aquatic life. Measurements made near shrimp farms near the Songkhla Lake Basin found that discharge of pond effluent increases BOD in nearby water bodies (Tanavud, 2001). Another report also found that shrimp aquaculture is the largest source of nitrogen and phosphorus inputs to the Bang Pakong Basin where wildlife such as fish, shrimp, and crocodile resides (Kupkanchanakul et al. 2015). More research must be done to determine the effects of shrimp effluent's effect on the surrounding organisms.

Shrimp effluent can also lead to eutrophication in surrounding waterways which can lead to the death of organisms that live in shrimp pond adjacent waterways. Shrimp effluent can lead to algae bloom and eutrophication, as this stops the sunlight and nutrients from passing the algae, this can cause shrimp death and can lead to adverse effects on coral reefs and fisheries (Tanan, 2000).

In 1995 the FAO developed a Code of Conduct (CoC) for Responsible Fisheries (FAO, 1995). The CoC of the Thai Department of Fisheries indicates that waste water that passes through settlement basis must require treatment. Many farms have also switched to semi-closed or closed systems, where there is little water exchange between farms. Recirculation technologies which exclude viral pathogens from the culture system can reduce effluent that is released into the surrounding environment. However, since the recirculation system is costly, few small farms can afford the technology (Goldburg, 1997).

<u>Antibiotics</u>

Antibiotics are used to treat bacterial diseases, and have no effect on viruses. However, antibiotics in Thailand are used by farmers preventatively, as many farmers believe that antibiotics make shrimp healthier. Viral disease outbreaks often results in an increase of of antibiotics as many farmers have misguided information concerning the application and use of antibiotics. A study conducted in 2000 interviewed 76 shrimp farmers in Thailand, and 74 percent of the farmers used antibiotics in their shrimp ponds. Thirteen different kinds of antibiotics were used, and some farmers used them daily and preventatively, and 60 percent of the farmers used antibiotics prophylactically (Holmstrom, 2002).

Antibiotics use can have negative effects on humans and shrimp. Humans, especially farmers who administer the antibiotics, risk exposure and antibiotic resistance as many of them use their bare hands to mix antibiotics with feed. Common antibiotics used in feed, such as norfloxacin, is also used for treating human pathogens, potentially causing resistance in some antibiotics for humans. Antibiotics can also cause resistance in shrimp pathogens, which can increase the difficulty in treating bacterial infections in shrimp ponds. Some antibiotics can also cause cross resistance, as some use of some antibiotics can lead to resistance in other antibiotics. For example, oxolinic acid and oxyetracycilne can lead to resistance to resistance to oxytetracycline, oxolinic acid and furazolidone in marine sediment (Nygaard et al., 1992). Furthermore, the use of antibiotics can also affect other organisms in the shrimp ponds. Administered antibiotics can leach from the feed pellets into pond water before they are consumed by the shrimp, or many of the antibiotics are uneaten and sink to the bottom of the pond. Antibiotics, such as chlortetracycline, are toxic to algae and aquatic invertebrates (Holten Lu¨tzhøft et al., 1999). Adverse effects on surrounding ecosystems may occur, as antibiotics such as oxytetracycline and oxolinic acid can be accumulated by fish, mussels, and crab, leading to potential resistance (Bjorklund € et al., 1990). However, more research must be done on the effect of administered antibiotics on shrimp farms to non-target aquatic organisms and humans (Weston, 2000).

The Code of Conduct published in 1995 indicated that antibiotics in aquaculture should be avoided, and administered antibiotics must be under veterinary supervision. As the code was voluntary, which will be further discussed in the next chapter, few farmers followed the code. However, a report by Chanratchakool in 1998 detailed the antibiotic policy recommendations by farmers. The report listed recommendations concerning shrimp farming such as only use antibiotics to treat bacterial infections, use antibiotics to which bacteria are sensitive, use fresh antibiotics, careful handling of the products considering human exposure, use of correct doses and durations, and apply adequate withdrawal periods (Chanratchakool et al., 1998). This lead to the spread of information on how to correctly administer antibiotics. Overtime, farmers became more knowledgeable about antibiotics and used fewer antibiotics. In the years between 2004 and 2016, only two batches of shrimp contaminated from Thailand were refused by the FDA (Shrimp Alliance, 2017).

Mangroves

Mangrove forests, made up of salt tolerant trees and shrubs, are efficient aquatic ecosystems that support a wealth of biodiversity. They are found in areas where there is brackish water, salt and freshwater. They protect coastal lands from erosion and minimize damage from natural disasters such as hurricanes and tsunamis. Mangrove roots process nutrients and absorb atmospheric gases, sustaining numerous nutrient cycling processes such as sulfate reduction. Mangrove forests are vital to tropical ecosystems as they not only serve as an important habitat for small aquatic organisms environmental bedrock for organisms, but also benefit communities by filtering polluted and runoff water, protecting lands from coastal and storm surges, and reducing the amount of greenhouse gases by absorbing carbon dioxide and storing it in their roots (Frost, 2018).

Although mangrove forests have proven to be environmentally beneficial, they are being destroyed at an alarming rate. From 1961 to 1966, the mangrove land coverage in Thailand was reduced by half of its original area (Wanthongchai, 2019). As mangrove forests are flooded with brackish water, the land is an ideal location for shrimp aquaculture (Páez-Osuna, 2001). While mangroves in Thailand are deforested due charcoal production, human habitation, salt mining, and agriculture; it is estimated that 20 to 50 percent of mangroves in Thailand up to 1936 have been deforested and converted into aquaculture, figure 19 shows an image of mangrove deforestation overtime (Thorton, 2003). However, statistics differ and the land conversion rate is expected to be higher, as many farms are not registered with the government. Moreover, many farmers abandon their old plot of land and find new farms once their shrimp has been contaminated with disease (Lebel, 2002).

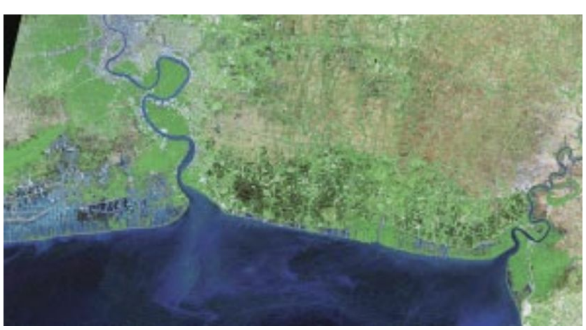


Figure 19: Left -Satellite image of the coast of Chanthaburi, Thailand, in 1973 filled with mangroves. Right - Satellite image of the coast of Chanthaburi, Thailand, in 2002, revealing the mangrove deforestation (Thorton, 2003)

While environmental damage is largely caused by the conversion of mangroves into shrimp farms, remaining mangroves that surround the farms can also be affected. As shrimp farms have a higher salinity concentration than mangrove forests, the discharge of high salinity water into the mangrove forests can alter the salinity of the brackish water, and detrimentally alter mangrove forests hydrology. (Wolanski, 2000). Furthermore, organic pollution from shrimp discharge may lead to eutrophication, and chemical contaminants (such as antibiotics) that can affect mangrove fauna (Tobey, 1998).

In recent years, Thailand's mangroves have started to recover due to government and community interest in their protection. The rate of mangrove lost in Thailand significantly decreased, and mangroves declined by one percent during 2000 and 2012 (Richard and Fries, 2016). As farmers switched to intensive farming, they discovered that mangroves were not suitable for their farms as mangrove soil becomes highly acidic and releases high levels of acid, iron, and aluminum once disturbed. This can decrease shrimp pond productivity and encourage pond abandonment (Chamberlain, 2010). During the second half of the 1990s, shrimp farms moved further inland over concerns about disease problems in coastal areas caused by poor water quality from shrimp farm waste. Farmers switched to low salinity culture systems from freshwater areas, and shrimp farm water was retrieved from freshwater through existing rice irrigation infrastructure located inland. By 1998, low-salinity shrimp ponds were responsible for 50 to 60 percent of Thailand's shrimp exports (Sivaraman, 2019).

Mangrove forests also received some protection in 2014, when the Thai government created a law that would not allow shrimp farms to operate in this habitat. Communities have also started to replant mangroves in their area with the help from NGO's such as YadFon which educates and helps communities with mangrove reforestation (Kongkaew, 2019). An article published by Returns in 2016 also indicated that farmers are also now integrating mangroves with shrimp farms, and figure 20 shows a mangrove integrated shrimp farm in Sam Roi Yot (Reuters, 2016). This type of farming is known as organic aquaculture, as no medicine nor chemical based can be used in the shrimp ponds that is integrated with reforested mangroves (Ahmed, 2017). While organic aquaculture yields are lower than intensive yields, organic shrimp are larger, and can sell at an average of $27 per kg compared to $14 per kg for intensive shrimp. Organic aquaculture is also more sustainable long term, as intensive farm ponds have to be abandoned often due to disease and pollution. However, disadvantages include concerns over shrimp farms' impact on mangrove growth (Reuters, 2016), and the fact that there is not enough research on organic farming's effect on the mangroves in the long term.

Figure 20: A mangrove integrated shrimp farm in Khao Sam Roi Yot, Thailand (Reuters, 2016)

Chapter 6: Solutions

Certifications

While there are international standards such as the Best Aquaculture Practice (BAP) and the Aquaculture Stewardship Council (ASQ) that can qualify shrimp farms for sustainability certifications (Pongpippatee, 2018), Thailand also has its own national certifications. Currently, Thailand's national certifications are the Good Aquaculture Practice (GAP), Code of Conduct (CoC), and the new and updated GAP standard which is also known as the GAP-7401 (Samerwong, 2018)[3]. Each of the certifications has their own requirements, allowing owners of different size shrimp farms to obtain different certifications. It is essential that shrimp farms attain a certification, as certifications make sure that farms are ascribing to environmental and labor laws, and thus working towards a sustainable future in shrimp farming.

Pressure from consumers and NGO's were essential in the development of certifications and Thai shrimp farms compliance with the regulations and certifications. After the 2013 EMS outbreak, the Thai government was eager to improve national standards to stop disease outbreaks and restore shrimp production. As many shrimp farmers left and abandoned their ponds for other employment (Pratruangkrai, 2015), the Thai government encouraged farmers to attain certifications that would keep their shrimp ponds healthy and mitigate disease. Overtime, more farms in Thailand started to attain certifications, illustrated by figure 21 (Samerwong, 2018).

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[3] Qualifications for GAP can be found here: https://www.acfs.go.th/standard/download/eng/Bio-shrimp.pdf, qualifications for CoC can be here: http://www.fao.org/fishery/legalframework/nalo_thailand/en#tcNB007E qualifications for GAP-7401 can be here: https://www.acfs.go.th/standard/download/eng/GAP-FOR-MARINE-SHRIMP-FARM_EN.pdf

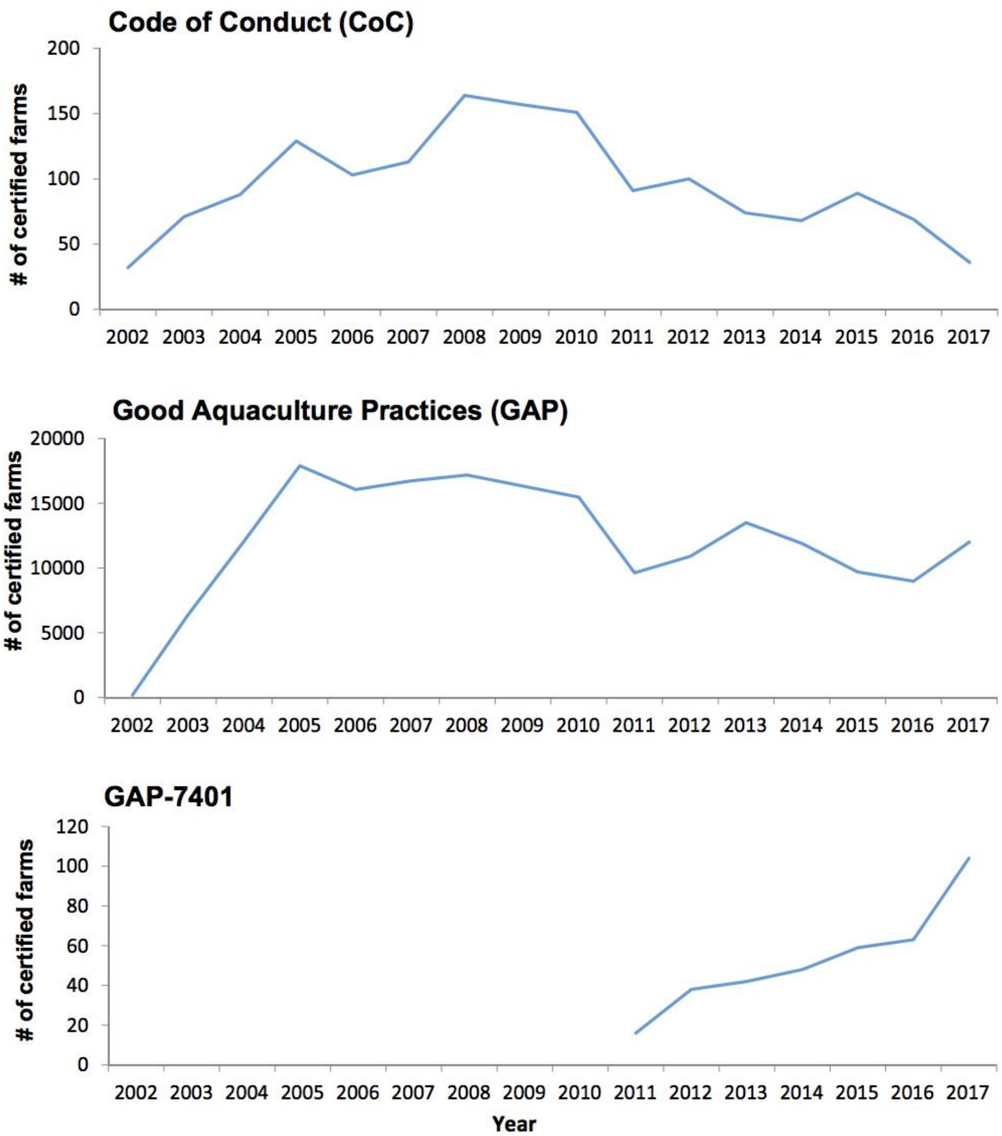

Figure 21: Shrimp farms in Thailand's compliance to national certifications overtime (Samerwong, 2018)

The Code of Conduct (CoC) was developed in 1998 to combat the antibiotic residues found in Thai shrimp which lead to import restrictions by the EU. The CoC combined international environment, aquaculture, and food safety guidelines, all of which satisfied the EU's import requirements that related to environmental sustainability and antibiotic residues (Serrano, 2005). However, only a small amount of farmers were able to attain the CoC standards, and as shown by figure 19, farms compliance with CoC has remained low. This was because participation was voluntary, along with most farmers having the perception that the standards were too demanding (Lebel, 2009).

The CoC was not seen as a viable certification that was able to meet the government's goal of increased shrimp production quality, leading to the Department of Fisheries to develop the Good Aquaculture Practice (GAP) standards in 2000 (Samerwong, 2018). This was achieved by providing minimum criteria for farms in good hygiene, food safety, and the prevention of chemical residues (Wilkings, 2012). The Department of Fisheries made the certificate mandatory to sell harvested shrimp to processing plants, raising participation rates.

In 2009, the Thai government created a new GAP, GAP-7401, to improve the international credibility of Thailand's shrimp aquaculture and combined qualifications from both the CoC and the GAP (ACFS, 2009). GAP-7401 was created to meet market demand whilst continuously protecting the environment, worker welfare, and social responsibility. However, by incorporating standards from the CoC such changing the layout of farms, it was met by resistance from farmers who did not want to comply to CoC's standards (ChuChou, 2013). Even with improved standards, the GAP-7401 is not accepted internationally. Most countries require international certificates for Thai shrimp.

Since 2000, the Thai government has created three different certifications, which has raised concerns about the reliability and consistency of Thai certifications in general. As of 2017, the Thai government is thinking of making a universal certification, and requiring that all farmers must be certified under GAP-7401. However, 12,000 farmers are certified with GAP, compared to 36 CoC and 104 GAP-7401 as of 2017 (Samerwong, 2018). This raises concerns about the likely reluctance of farmers who are not willing or not able to afford new technology that will enable them to switch to the GAP-7401. In the unlikely scenario that farmers all switch to the GAP-7401, the certification is still not accepted globally. It can be argued that the Thai government should abandon national certificates and switch to International sustainability certifications. This will decrease confusion among farmers concerning what certification to get, and the certification will be accepted worldwide. The two most popular International shrimp certifications are from the Aquaculture Stewardship Council (ASC) and the Best Aquaculture Practices (BAP)[4]. International certifications do not have a strong presence in Thailand, and so it is the Thai government's responsibility to promote the benefits and global superiority of International certifications over Thai certificates to shrimp farmers, and make the certificate mandatory to all operating shrimp farms.

Technological Advancements

Technology must continue to develop to alleviate environmental impacts that surround shrimp farming. Companies such as New Wave Foods, a startup that develops plant based shrimp made from seaweed and other natural ingredients, is providing a shrimp alternative to customers who want shrimp with fewer environmental impacts

[4] Qualifications for ASC can be found here: https://www.asc-aqua.org/what-we-do/our-standards/farm-standards/the-shrimp-standard/

than farmed shrimp. The company claims that their alternative shrimp tastes like shrimp and is lower in calories and salt than real shrimp (New Wave Foods). New Wave Foods is one of the first companies to create plant based shrimp, and as of 2019 the company is still in Beta testing, so there is no data to show if customers are willing to purchase the product. However, surveys show that 30 to 50% of people in the US want to cut down on meat, and 95 percent of people who bought plant based burgers in 2014 were meat eaters (Pratruangkrai, 2015). This data suggests that there is a willing market that is ready and wants to buy plant based shrimp.

Another emerging technology that reduces shrimp farming's effluent environmental effects is the Aquapod. Companies such as InnovaSea has developed fish pens called the Aquapod, illustrated in figure 22, that can be kept in the ocean to allow fish to be farmed without them being taken out of their natural environment. The Aquapod allows farmers to deposit their fish into the pod and leave it adrift in the ocean, and the engines are used to correct the course of the floating farm. However, the Aquapod has not been tested with shrimp, and so it would be uncertain if shrimp would be able to thrive in the Aquapod. The cost of the Aquapod may also be significantly higher than the cost of intensive traditional shrimp farms, and more research must be done to see if an Aquapod is economically feasible for farmers (InnovaSea).

While both these companies and their technology is not yet available in Thailand, it is essential that technology keep advancing so that it can spread globally, and become accessible in Thailand.

Figure 22: Aquapod in the Ocean (InnovaSea)

Closed System Aquaculture

The close systems does not allow waste to enter the external environment. It does this by recirculating pond waters through recycling and effluent water by filtration systems or integrating secondary containment ponds. The system also eliminates detrimental environmental inputs that open systems use such as pollution from coastal water exchange. One such system was developed by Texas A&M University, which in 2017, implemented a fully functioning, enclosed small scale closed system production facility in Port Aransas, Texas. The researchers hope to produce shrimp that will both meet market demands and be environmentally sustainable. Their goal is to produce one million pounds of shrimp per year (National Institute of Standards and Technology, 2017). However, it may take several years for closed systems to be adopted in Thailand,

and not enough research has been done to see if *P.Vannamei* could grow in closed systems, or if closed systems would be feasible in Thailand's environment.

Vertical Integration

Vertical Integration involves combining the supply chain of the shrimp aquaculture industry into one company. Companies own everything including the feed producers, processing plants, hatcheries, and farms. For example, companies such as Thai Union own everything in their supply chain, and all of their shrimp farms, hatcheries, and feed mills all hold the BAP certification (Thai Union, 2018). As companies vertically integrate small farms into their business, this forces smaller farms to adhere to the company's stricter labor policies and environmental standards. Furthermore, as larger companies often uses higher quality broodstock, this can reduce the risk of disease and environmental impacts (Goss, 2000). Although farmers may lose sovereignty of their farms once they integrate with larger companies, integration provides more economic stability, and forces farmers to adhere to stricter environmental standards.

Chapter 7: Conclusion

While shrimp farming in Thailand and globally contributes to a multitude of social and environmental problems, it is important to consider the issue holistically. While there are workers in peeling sheds who are being exploited and mangroves that are being deforested, it is important to acknowledge that positive changes in the shrimp industry is possible. Shrimp farming in Thailand is a source of income to many farmers, and it can make a substantial contribution to rural development, and it continues to contribute to the Thai economy. Over time, shrimp farming in Thailand has started to become more sustainable as farmers continue to strive for environmental sustainability in their shrimp ponds and the government starts to enforce stricter labor laws. However, more research still needs to be undertaken to continue to find ways to make shrimp farming more environmentally sustainable while continuing to meet global shrimp demand and provide a livelihood for farmers.

Realistically most people will not stop eating shrimp in the near future, even if they know the negative effects of shrimp farming. While I do not have the answer if shrimp farming in Thailand can retain current shrimp production whilst maintaining sustainability, I am hopeful. The answer starts with us, the customer, in becoming aware. It is important to acknowledge that some of the shrimp sold in supermarkets and restaurants worldwide may have been farmed and processed by slaves, and/or have contributed to environmental degradation. It is essential that consumers are educated about the issues that surround the controversial process surrounding shrimp farms, not just in Thailand but worldwide. By being aware, customers can and must demand for ethically produced shrimp with sustainability certifications from both the government and from the companies producing shrimp. In the short term, the companies and government may have to spend money to ensure that all farms have the technology needed to become sustainable. However, in the long term, all shrimp farms in Thailand will become fully traceable and sustainable. As customers were the ones who demanded for sustainable shrimp, they will buy the sustainable shrimp that is given to them. At the end of the day it is up to the consumers to demand better and to change the global shrimp industry.

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