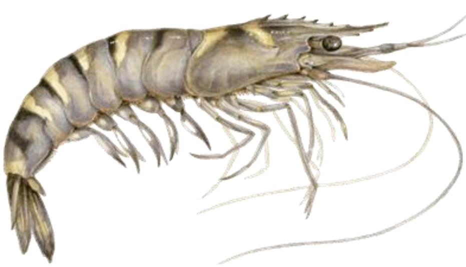
Giant Tiger Prawn

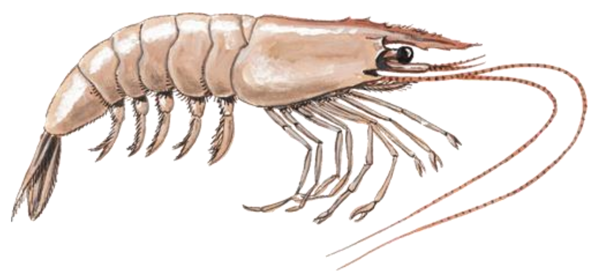
Penaeus monodon



© Monterey Bay Aquarium

Whiteleg Shrimp

Litopenaeus vannamei



©Scandinavian Fishing Yearbook

Vietnam
Ponds

September 5, 2017

Seafood Watch Consulting Researchers

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Final Seafood Recommendation

Giant tiger prawn

Penaeus monodon

Vietnam

Integrated shrimp-mangrove pond (Silvoculture)

Criterion	Score (0-10)	Rank	Critical?
C1 Data	4.38	YELLOW	
C2 Effluent	10.00	GREEN	NO
C3 Habitat	1.13	RED	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	6.00	YELLOW	NO
C7 Disease	5.00	YELLOW	NO
C8 Source	5.00	YELLOW	
C9X Wildlife mortalities	0.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**41.51**		
Final score	**5.19**		

OVERALL RANKING

Final Score	5.19
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	NO

FINAL RANK
RED

Scoring note – Scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact. Two or more red criteria, or 1 Critical criteria trigger an overall Red recommendation.

Summary

The final numerical score for extensively farmed giant tiger prawn *(Penaeus monodon)* in integrated shrimp-mangrove ponds in Vietnam is 5.19 out of 10, which is in the Yellow range. But with two Red criteria, the final rank is Red and an “Avoid” recommendation.

Final Seafood Recommendation

Giant tiger prawn
Penaeus monodon
Vietnam
Extensive pond

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.44	YELLOW	
C2 Effluent	10.00	GREEN	NO
C3 Habitat	1.13	RED	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	6.00	YELLOW	NO
C7 Disease	5.00	YELLOW	NO
C8 Source	0.00	RED	
C9X Wildlife mortalities	–4.00	YELLOW	NO
C10X Introduced species escape	0.00	GREEN	
Total	**31.57**		
Final score	**3.95**		

OVERALL RANKING

Final Score	3.95
Initial rank	YELLOW
Red criteria	3
Interim rank	RED
Critical Criteria?	NO

FINAL RANK
RED

Scoring note – Scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact. Two or more red criteria, or 1 Critical criteria trigger an overall Red recommendation.

Summary
The final numerical score for extensively farmed giant tiger prawn *(Penaeus monodon)* in ponds in Vietnam is 3.95 out of 10, which is in the Yellow range. But with three Red criteria, the final rank is Red and an “Avoid” recommendation.

Final Seafood Recommendation

Whiteleg shrimp

Litopenaeus vannamei

Vietnam

Intensive pond

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.33	YELLOW	
C2 Effluent	6.00	YELLOW	NO
C3 Habitat	1.13	RED	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	5.78	YELLOW	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	5.00	YELLOW	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	–4.00	YELLOW	NO
C10X Introduced species escape	–4.00	YELLOW	
Total	**27.24**		
Final score	**3.41**		

OVERALL RANKING

Final Score	3.41
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	NO

FINAL RANK
RED

Scoring note – Scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact. Two or more red criteria, or 1 Critical criteria trigger an overall Red recommendation.

Summary

The final numerical score for intensively farmed whiteleg shrimp *(Litopenaeus vannamei)* in Vietnam is 3.41 out of 10, which is in the Yellow range. But with two Red criteria, the final rank is Red and an "Avoid" recommendation.

Executive Summary

Shrimp is the most widely consumed seafood item in the United States; in 2013, Americans ate an estimated 1.6 kilograms (kg) per capita. It has been estimated that 90% of the shrimp consumed in the U.S. are imported. In 2015, the United States imported 60,677 MT of shrimp from Vietnam. Vietnam is the fifth-largest supplier of shrimp to the United States, accounting for 10% of total U.S. shrimp imports.

Two main marine shrimp species are farmed in Vietnam: the native giant tiger prawn *(Penaeus monodon)* and the non-native whiteleg shrimp *(Litopenaeus vannamei).* Whiteleg shrimp was illegally introduced in 2000, but is now legally imported. In 2008, the Vietnamese government reversed earlier legislation (2004) banning the production of whiteleg shrimp in the main shrimp farming region of the Mekong River Delta. Whiteleg shrimp production was first reported in 2002 with 10,000 MT and has increased to nearly 310,000 MT in 2014, whereas the native giant tiger prawn production has decreased from its peak production in 2008 of approximately 325,000 MT to just under 170,000 MT in 2014. Despite the drop in production, Vietnam is the largest producer of farmed giant tiger prawn.

This report assess the three predominant production systems in Vietnam, including integrated shrimp-mangrove pond systems (i.e., silvofishery) and extensive ponds used for giant tiger prawn farming, and intensive ponds used for whiteleg shrimp. Integrated shrimp-mangrove systems are characterized by extensive farming practices (low stocking density, little or no inputs such as feed) with mangrove trees planted in the ponds themselves or on land within the farm boundary, and are stocked with both passively collected and supplemental hatchery-raised seed (estimated in this report to be approximately a 50:50 ratio). Extensive giant tiger prawn farming is characterized by generally small farm operations with little to no input (e.g., supplemental feed), high water exchange, and little management control (including biosecurity), but largely stocked with hatchery-raised seed (estimated in this report to be approximately 99% hatchery sourced with 1% passive collection). The intensive farming of whiteleg shrimp is characterized by low water exchange (0%–3% daily), use of commercial feeds, chemical inputs, mechanical aeration, enhanced biosecurity measures, and higher stocking densities of hatchery-reared farm seed.

For an industry as large and globally important as Vietnamese marine shrimp farming, data are surprisingly lacking. There is little of value published, in English, about the key government agencies responsible for the regulation of marine shrimp farming, except for production data from the General Statistics Office of Vietnam's website. This report relies on a few leading studies into key issues of concern or into the particular production systems. These studies also tend to be based on quite small sample sizes (i.e., surveys of fewer than 70 farms). Additional information was also accessed by personal communication with industry experts. Slight differences in the data available between the production systems resulted in overall scores of 3.33 out of 10 for whiteleg shrimp, 4.38 out of 10 for integrated shrimp-mangrove systems, and 3.44 out of 10 for extensive giant tiger prawn systems for Criterion 1 – Data.

The two main production systems for giant tiger prawn operate without the use of supplemental feed; although the extensive system may add fertilizer, it is insufficient to create a source of pollution. Thus, both systems were assessed using the Effluent Evidence-Based Assessment and found not to cause a concern to the environment, resulting in a score of 10 of 10 for Criterion 2 – Effluent.

Whiteleg shrimp farms are intensive and rely on additional feed, but fertilizers are rarely used. No effluent data are published for the Vietnamese whiteleg shrimp industry, so it was assessed using the Effluent Risk-Based Assessment methodology. Relatively low FCRs using high protein feeds resulted in a moderate 51.52 kg of nitrogen-based waste produced per ton of whiteleg shrimp. Waste released to the environment is further decreased by little to no exchange of water, except at harvest and proper sludge disposal; approximately 10%, or 5.15 kg N/t, is discharged from the farm, resulting in a score of 9 out of 10 for whiteleg shrimp for Factor 2.1. Regulation in Vietnam has been criticized for not responding quickly to the growth of the industry. Effluent regulations exist, including farm effluent water quality standards and regional water quality standards, but these are generally not applied during the permitting process because most new farms are below the size limit required for such measures. The results of regulatory monitoring were not forthcoming, and data on pollution impacts were also scarce; those that were available suggested that impacts were occurring. The lack of effective regulation and enforcement results in a score of 0.55 out of 10 for whiteleg shrimp for Factor 2.2. But the amount of waste discharged was very low, so the final score is 6 out of 10 for whiteleg shrimp for Criterion 2 – Effluent.

Globally, shrimp farming has been linked to the historical conversion of ecologically important wetlands, including mangrove forests. Vietnam is no exception, with two-thirds of the country's forests converted for aquaculture between 1980 and 2000. These losses were exacerbated by the disturbance of acid soils created during pond construction, which in some cases created extreme acidification, damaged remaining mangroves, and resulted in ponds being abandoned, with new areas being cleared for new ponds. Recent studies indicate a moving picture of both conversion and restoration to and from all three production systems assessed in this report, with one reviewer suggesting that further losses were unlikely. Because the weight of evidence demonstrates recent (but not necessarily widespread) ongoing conversion of high value habitats, the score for Factor 3.1 for all production systems is 3 out of 10. Integrated shrimp-mangrove systems are legally required to maintain 60% mangrove coverage and should be eligible for a much higher score (7 out of 10), but the available evidence suggests that the law is not being enforced; mangrove coverage is generally much lower (≈30%). In addition, the mangroves are considered a harvestable crop, and a single species is planted (rather than multiple species, which are found in virgin habitat), which results in their ecosystem services being significantly less than those of undisturbed mangrove forests. Given that mangroves have recently been converted to build this type of farm, integrated shrimp-mangrove systems also receive a score of 1 out of 10 for Factor 3.1.

All the production systems were considered together on habitat management. Low scores were given primarily as a result of the promotion of shrimp farming over habitat protections, especially at the local government level. Historically, regulation has been slow to address the growth of the industry. Although current regulations exist, including environmental impact assessments (EIAs) that include public engagement, they only apply to large farms and not the smaller farms that make up the majority of the industry. Data are also lacking on enforcement, but a key example of its failure is the inability to enforce the 60% mangrove coverage rules in the integrated shrimp-mangrove systems. There is potential for improvement in the future, particularly through a World Bank project that includes integrated spatial planning of all coastal areas and across sectors. Factor 3.2 was scored as 1.4 out of 10 for all production systems.

Overall, the combination of recent critical habitat losses with insufficient enforcement of regulation gives a final Criterion 3 – Habitat numerical score of 1.13 out of 10 for all production systems. It should be noted that suitable verification of legal compliance would be sufficient to obtain a higher habitat score for all production systems, particularly the integrated shrimp-mangrove system.

Asian shrimp aquaculture is known to use a variety of chemicals over the course of the production cycle, though the environmental impacts of these are not always known. Of significant concern is the use of antimicrobials, which proliferate resistant pathogens that affect shrimp health and potentially human health. Detailed data on chemical or antibiotic usage in Vietnam are not available. Reports range from minimal usage of chemicals and antibiotics to reports that WHO-listed, critically important and highly important antimicrobials are being used on Vietnamese shrimp farms. Still, there is clear evidence from U.S. FDA and EU import rejections and in the literature that illegal antibiotic use is occurring. A fundamental issue could be that uninformed farmers can access antibiotics without a prescription. The evidence available is sufficient to warrant a score of 0 out of 10 for Criterion 4 – Chemicals for more intensive production (i.e., whiteleg shrimp). There is potentially less clarity with the extensive systems used for giant tiger prawn, but there is no way to differentiate production systems or species linked to the majority of import rejections (except for two rejections by the EU that specifically refer to giant tiger prawn). From the precautionary perspective, all the production systems must be considered linked to illegal chemical use, so a score of 0 out of 10 for Criterion 4 – Chemicals is given for both giant tiger prawn systems.

The two main production systems for giant tiger prawn operate without the use of supplemental feed, resulting in a score of 10 out of 10 for Criterion 5 – Feed.

Whiteleg shrimp is farmed utilizing compound feed that contains relatively high amounts of fishmeal (20%) but only small amounts of fish oil (2%). The average FCR is relatively low (1.25), resulting in a Fish In:Fish Out (FIFO) value of 1.11. Current data on Vietnamese sources of fishmeal and fish oil that are used as ingredients in shrimp feeds were unavailable; this unknown status resulted in a Factor 5.1b score of –6 out of –10. The net protein loss from feed was 63.2%, with an estimated feed footprint of 7.15 ha of ocean area and 0.37 ha of land area per ton of whiteleg shrimp production. Overall, the final score for whiteleg shrimp is 5.78 out of 10 on Criterion 5 – Feed.

Both giant tiger prawn systems frequently exchange water and present a high risk of escapes; however, the low stocking densities used result in score of 5 out 10 for Factor 6.1a. Both systems also supplement ponds with wild seed that is passively collected when the ponds are filled with hatchery-raised seed from wild-caught broodstock. These seed represent a very minor risk of impact to the local wild stocks because they are one generation and hatchery-raised, and result in a Factor 6.1b score of 8 out of 10. Ultimately, the final numerical score is 6 out of 10 for Criterion 6 – Escapes for both giant tiger prawn systems.

Whiteleg shrimp farms limit water exchange and maintain infrastructure that reduces the risk of escape. The score for Factor 6.1a is 6 out of 10. Whiteleg shrimp is nonnative to Vietnam and raised from imported broodstock, potentially having a larger escapement impact if it were to become ecologically established. Although establishment has not been shown in other countries where the species has been introduced, it remains poorly studied. The score for Factor 6.1b is 4.5 out of 10. Overall, whiteleg shrimp is considered to have a moderate risk of escapement and a moderate risk for impact, resulting in a score of 4 out of 10 for Criterion 6 – Escapes.

Diseases can be extremely damaging to shrimp farms but are less pronounced on extensive farms than intensive farms. As a result, intensive farming may present a higher risk of disease outbreaks. In Vietnam, intensive farms are required by law to apply much stronger biosecurity measures than extensive farms. Conversely, poor management of disease-contaminated water in extensive farming has the greatest potential to spread diseases to other farms and/or wild populations. The tradeoffs between the two production strategies mean that all production systems can be assessed together in terms of their risk to wild populations. Though many shrimp diseases can be transferred to wild populations of shrimp and other species, the actual impact of on-farm disease on wild populations remains unclear. The various considerations mean that there is a moderate concern for disease-related impact in Vietnam, resulting in a final score of 5 out of 10 for Criterion 7 – Disease.

Whiteleg shrimp depends entirely on hatchery-raised seed from domesticated broodstock and scores 10 out of 10 for Criterion 8 – Source of Stock. Both integrated and extensive giant tiger prawn systems use both passively collected post larvae (PLs) and hatchery-raised seed from wild harvested broodstock. Data are exceedingly limited on the wild broodstock stocks, so they cannot be considered sustainable. Based on an estimated 50% and 1% use of passively collected PLs on integrated shrimp-mangrove and extensive giant tiger prawn farms, respectively, the final score for Criterion 8 – Source of Stock is 0 out of 10 for extensive ponds and 5 out of 10 for integrated shrimp-mangrove systems.

Recent data on wildlife and predator mortalities associated with Vietnamese shrimp farming are lacking. General shrimp farming practices include treating ponds during the initial fill to kill resident organisms, but no specific measures used in Vietnam were found. Integrated shrimp-mangrove systems are an exception to this strategy, and do not generally remove predatory organisms. Passive and nonlethal measures, such as pond linings to deter predatory crabs and fireworks to deter diving birds, are also common in shrimp farming, but use of these practices could not be confirmed. Interactions between wildlife and shrimp ponds that result in mortality do likely occur on extensive giant tiger prawn farms and whiteleg shrimp farms, but are not thought to result in population-level impacts. Whiteleg shrimp and extensive giant tiger prawn systems each score a moderate deduction of –4 out of –10 for Criterion 9X – Wildlife and Predator Mortalities, whereas integrated shrimp-mangrove systems have no deduction (0 out of –10).

Giant tiger prawn is native to Vietnam, and in addition to passive stocking during pondwater exchanges, domestic hatchery-raised seed supplements both extensive production systems. Therefore, neither extensive systems nor integrated farming systems rely on international or trans-waterbody shrimp movements, and both giant tiger prawn systems score 10 out of 10 for Criterion 10X – Escape of Unintentionally Introduced Species. Whiteleg shrimp is not native to Vietnam; in 2009, 20% of the broodstock in Vietnam was imported from biosecure U.S. broodstock centers and 80% from "poor quality" Asian (most likely Chinese) broodstock centers—but current data suggest that the contribution from U.S. facilities may have increased substantially. Whiteleg shrimp farming therefore relies 100% on imported broodstock, resulting in a score of 0 out of 10 for Factor 10Xa. The mix of highly biosecure broodstock from the U.S. with less-biosecure regional sources, in conjunction with reasonable farm-based biosecurity measures (e.g., harvest water-exchange), results in a moderate score of 6 out of 10 for Factor 10Xb. The scores for Factors 10Xa and 10Xb are combined to result in a total deductive score of –4 out of –10 for whiteleg shrimp for Criterion 10X – Escape of Unintentionally Introduced species.

Overall, the two giant tiger prawn systems have Yellow-ranked numerical scores as a result of extensive practices, but both systems have at least two Red criteria, which result in an overall Red ranking. Intensive non-native whiteleg shrimp farming, with its higher stocking densities and use of compound feeds, presents more of a risk to the environment. Although it has greater controls in place to address such risks, including the use of domesticated broodstock versus the reliance on wild caught broodstock (as in the farming of giant tiger prawns), it still ranks Red overall. The main drivers of the Red rankings for all systems stem from the ineffective regulatory control of both antibiotics and habitat impacts. This report highlights evidence of quite recent loss of ecologically important mangrove forests for all systems; this might be the most surprising for the integrated shrimp-mangrove systems, but the available evidence suggests that only the farm itself, and not the surrounding ecosystem, benefits from the ecological services provided by the contained mangroves, particularly where farms do not comply with the legally required 60:40 mangrove-to-farming-area ratio. The precautionary Red ranking on chemicals for all systems relates directly to substantial evidence that illegal drug usage is a current issue in Vietnamese shrimp farming and to the lack of an effective prescription-based regulatory system for their legal use. Although it would be expected that extensive systems would not use antibiotics, there is no way to differentiate production systems or species linked to import rejections in the United States, but two recent EU rejections specifically refer to antibiotic residues in giant tiger prawn shipments. In addition, several U.S.-rejected containers came from processing plants in regions where extensive farming dominates.

Table of Contents

Introduction

Scope of the analysis and ensuing recommendation

Species
Giant/Black tiger prawn *(Penaeus monodon)*
Whiteleg shrimp *(Litopenaeus vannamei)*

Geographic coverage
Vietnam

Production methods
Giant tiger prawn:
- Integrated shrimp-mangrove pond systems (Silvoculture)
- Extensive ponds

Whiteleg shrimp:
- Intensive ponds

Species Overview

Two species dominate the marine shrimp farming industry in Vietnam: the native giant tiger prawn *(P. monodon)* and the non-native whiteleg shrimp *(L. vannamei)* (Duijn et al. 2012). Whiteleg shrimp was initally introduced illegally in 2000, but is now legal (FAO 2013) (VASEP 2014) (Nair 2015). In 2008, the Vietnamese government reversed earlier legislation (2004) banning the production of whiteleg shrimp in the Mekong River Delta (FAO 2013) (VASEP 2014) (Nair 2015) (Quoc 2016). These shrimp species share a similar life history, in which adults spawn offshore, larvae move toward the coast and develop in estuaries, and then move offshore as adults (Briggs 2006) (Kongeo 2005).

Production statistics
Figure 1 shows farmed shrimp production in Vietnam from 2000 to 2014. Whiteleg shrimp production was first reported in 2002 with 10,000 metric tons (MT) and increased to nearly 310,000 MT in 2014, whereas giant tiger prawn production has decreased from its peak production in 2008 of approximately 325,000 MT to just under 170,000 MT in 2014 (FAO 2016a). Despite the drop in production, Vietnam is the largest producer of farmed giant tiger prawn (Jonell and Henriksson 2014) (VASEP 2014).

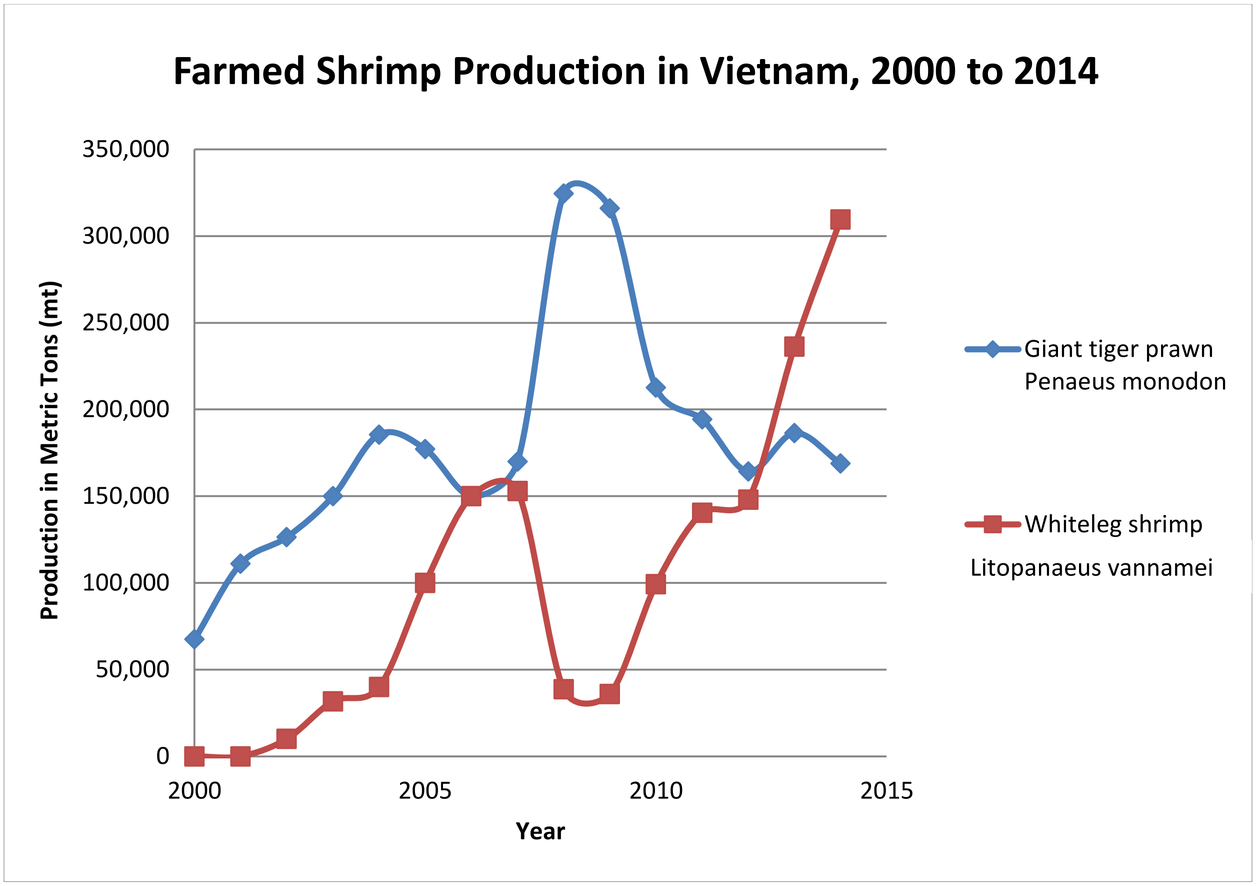


Figure 1. Farmed shrimp production in Vietnam between 2000 and 2014 (FAO 2016a).

Import and export sources and statistics

Over the past two decades, Vietnam has emerged as a major supplier of seafood: approximately 90% (631,457 MT in 2014) of its farmed shrimp production is currently exported to international markets (Duijn et al. 2012) (Nair 2015) (GSO 2016). Currently, shrimp represents the principal seafood export and accounts for 44% of the total value for exported seafood in Vietnam (VASEP 2014) (Thu 2016).

Shrimp is the most widely consumed seafood item in the United States; in 2013, Americans ate an estimated 1.6 kilograms (kg) per capita (NFI 2015). It has been estimated that 90% of the shrimp consumed in the U.S. are imported (Fluech and Krimsky 2011). In 2015, Vietnamese shrimp were exported to 92 markets (46 countries) (Nair 2015) (Thu 2015a). The top 10 markets included the United States, Japan, the European Union, China, South Korea, Canada, Australia, Taiwan, ASEAN member states, and Switzerland. These markets provide over 90% of Vietnam's total shrimp export value (Thu 2016). Whiteleg shrimp made up 58.6% of Vietnam's total shrimp exports, whereas giant tiger prawn exports constituted 33% of the country's total (Thu 2015).

Figure 2. Annual US shrimp imports from Vietnam. Source: USDA 2016

In 2015, the U.S. imported 60,677 MT of shrimp from Vietnam (Figure 2). Vietnam is the fifth-largest supplier of shrimp to the United States and represents 10% of total U.S. shrimp imports (USDA 2016). According to statistics from Vietnam Customs, the estimated value for 2015 shrimp exports to the United States was USD 3 billion (Thu 2016).

Common and market names

Table 1 lists relevant common and market names for giant tiger prawn and whiteleg shrimp.

Table 1. Relevant common and market names for giant tiger prawn and whiteleg shrimp

Scientific Name	*Penaeus monodon*	*Litopenaeus vannamei*
Common Name	Black tiger prawn, giant tiger prawn, tiger shrimp, or shrimp	Pacific white shrimp, whiteleg shrimp, western white shrimp, or shrimp
United States	Giant tiger prawn	Whiteleg shrimp
Vietnam	*Tôm sú*	*Tôm thẻ chân trắng*
Japanese	*Ushi-ebi (うしえび)*	*Banamei-ebi (ばなめいえび)*
Spanish	*Langostino jumbo*	*Camarón patiblanco*
French	*Crevette géante tigrée*	*Crevette pattes blanches*

Product forms

Although shrimp exported from Vietnam are available in a number of product forms, including frozen or previously frozen, most of the shrimp is shipped in frozen-raw form (Thu 2015a). In addition to cooked or raw, head-on or head-off, tail-on or tail-off, shell-on, peeled, and deveined forms, processors have recently sought to differentiate their product lines by introducing value-added products such as sushi, skewered, breaded, tempura, marinated, and shrimp bites (Minhphu 2016).

Analysis

Scoring guide

- With the exception of the exceptional criteria (9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional criteria result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available on the Seafood Watch website. http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_AquacultureCriteraMethodology.pdf
- The full data values and scoring calculations are available in Appendix 1

Production system

In Vietnam, shrimp farming can be traced back more than 100 years, and only nonindustrialized extensive shrimp farming techniques were practiced until the 1980s (Omoto 2012) (pers. comm., Tung 2014) (Quoc 2016). Although significant expansion of the sector began after the implementation of the *Doi Moi* or "Renovation" Reform Policies in 1986, the implementation of technological innovations in other Asian nations (e.g., Thailand) that led to a boom in industrialized shrimp farming during the 1980s was limited in Vietnam at the same time (Omoto 2012).

Although Vietnam has historically produced giant tiger prawn, commercial production of this species only began in the 1990s and then accelerated in the 2000s (Nair 2015). One reason for this expansion was its introduction to the Mekong River Delta in 1997 (Quoc 2016). In 1999, the introduction of the *Aquaculture Development Plan (1999–2010)* led to further growth of the shrimp farming industry (Gardeau et al. 2012). In 2000, the Vietnamese government officially encouraged expansion of the industry by permitting farmers to convert low-productivity, coastal saline agricultural fields (i.e., rice paddies) into shrimp ponds. Only in the past 15 years or so has the Vietnamese shrimp farming industry begun to utilize more intensive farming methods for this species (Omoto 2012).

Whiteleg shrimp was illegally introduced in 2000, but is now being legally imported and raised in intensive production systems (FAO 2013) (VASEP 2014) (Nair 2015). In 2008, the Vietnamese government reversed earlier legislation (2004) banning the production of whiteleg shrimp in the Mekong River Delta (FAO 2013) (VASEP 2014) (Nair 2015) (Quoc 2016). Compared to giant tiger prawn, whiteleg shrimp exhibits several beneficial culture characteristics, including resistance to specific diseases, tolerance of higher stocking densities, faster growth rates, lower protein requirements (a more efficient feed conversion ratio [FCR]), and better survival under adverse environmental conditions (Ha et al. 2010). Whiteleg shrimp was introduced as a more productive shrimp species that is also more competitive in international markets in comparison to domestically grown giant tiger prawn (Duijn et al. 2012). As a result, a large proportion of previous semi-intensive and intensive giant tiger prawn farmers have switched to whiteleg shrimp culture, as was shown in Figure 1 (*see* Introduction) (Hirai et al. 2013) (pers. comm., Luu 2014).

Throughout Vietnam, shrimp farms are now located in 30 different provinces (pers. comm., Bich 2013). Figure 3 shows the distribution of shrimp farming along the 3,444-km coast of Vietnam (excluding islands) (CIA 2013); the bulk of production (≈80%) is primarily centered in the Mekong River Delta (Corsin 2011). The growth in these southern provinces comes largely from the region's expansive saltwater intrusion zone (Figure 4), which expands seasonally but also exists on a permanent, year-round basis (Omoto 2012). Moreover, the relatively consistent climate in this region allows farmers to produce shrimp on a nearly year-round basis (Nair 2015).

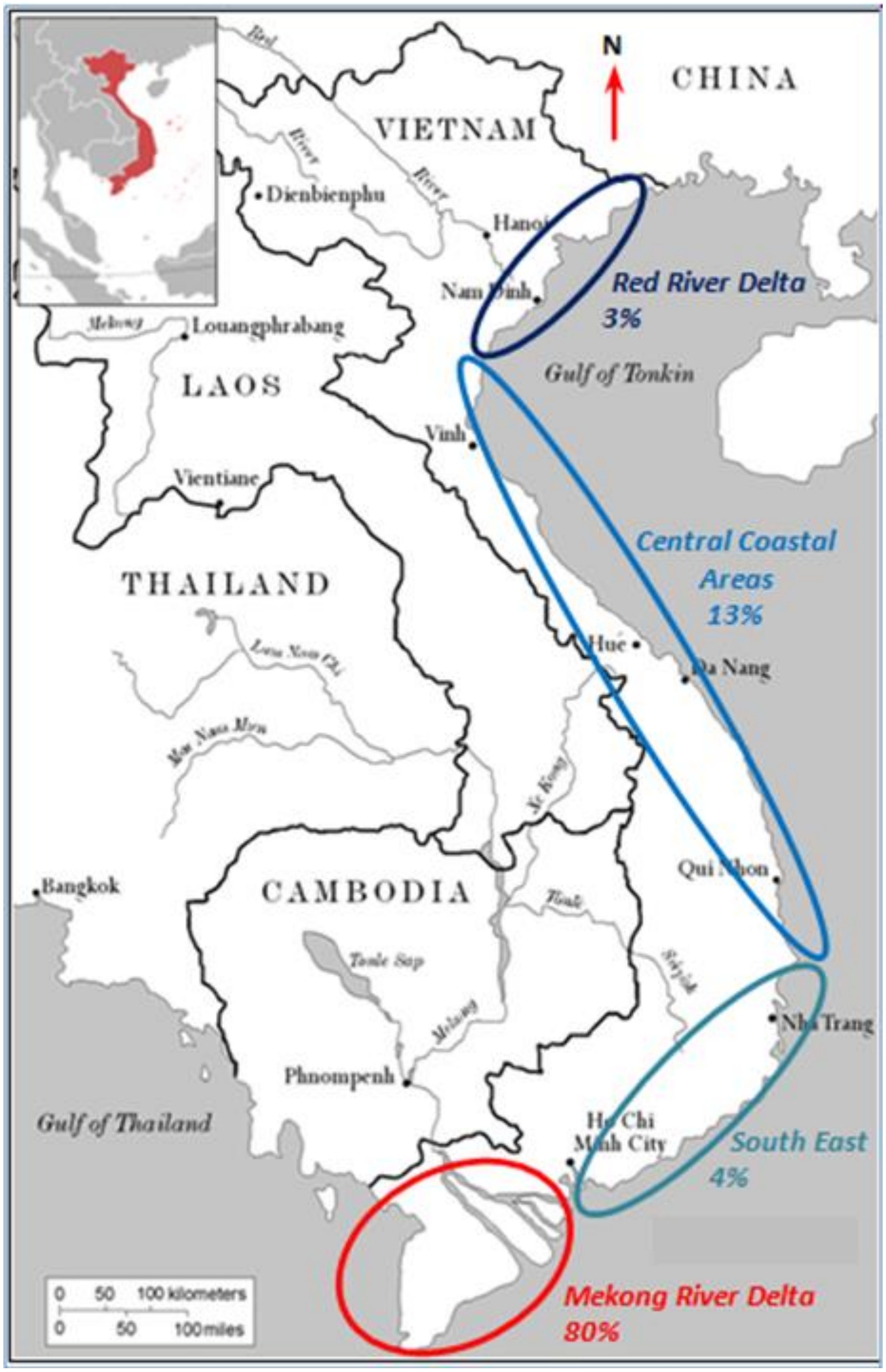


Figure 3. Farmed shrimp production area by region (Source: [Directorate of Fisheries 2015] [Joffre et al. 2015] [GSO 2016], map from www.alabamamaps.ua.edu)

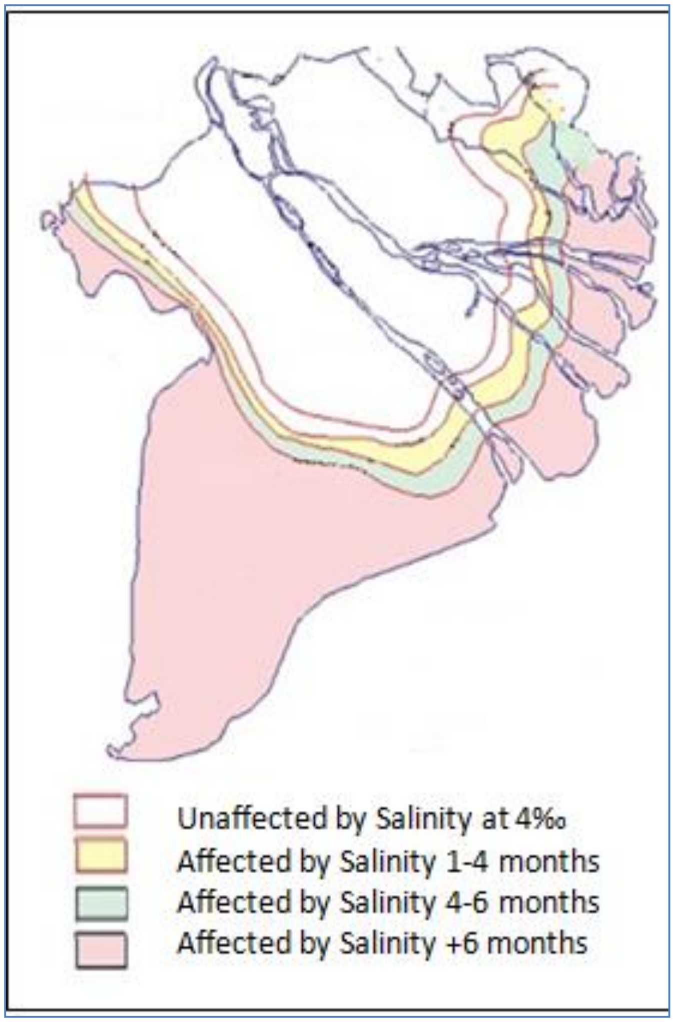


Figure 4. Saltwater intrusion in the Mekong River Delta (adapted from Brennan et al., 2002).

Giant tiger prawn is currently the primary culture species in the Mekong River Delta (FAO 2013) (Quoc 2016). Over 90% of the total production area in the provinces of the Mekong River Delta is dedicated to giant tiger prawn farming, with the remaining area used for whiteleg shrimp (Corsin 2011) (Duijn et al. 2012) (Lan 2013) (VASEP 2016) (Quoc 2016). Although there is an increasing trend toward intensification, extensive ponds and integrated shrimp-mangrove ponds are the major systems in southern Vietnam and cover more than 85% of the production area in the region (Lan 2013) (Tran et al. 2015). Since 2006, the shrimp farming industry has surpassed a total farming area of 600,000 ha in Vietnam (Figure 5). According to the Directorate of Fisheries, the total shrimp farming area in Vietnam rose to 677,459 ha in 2015.

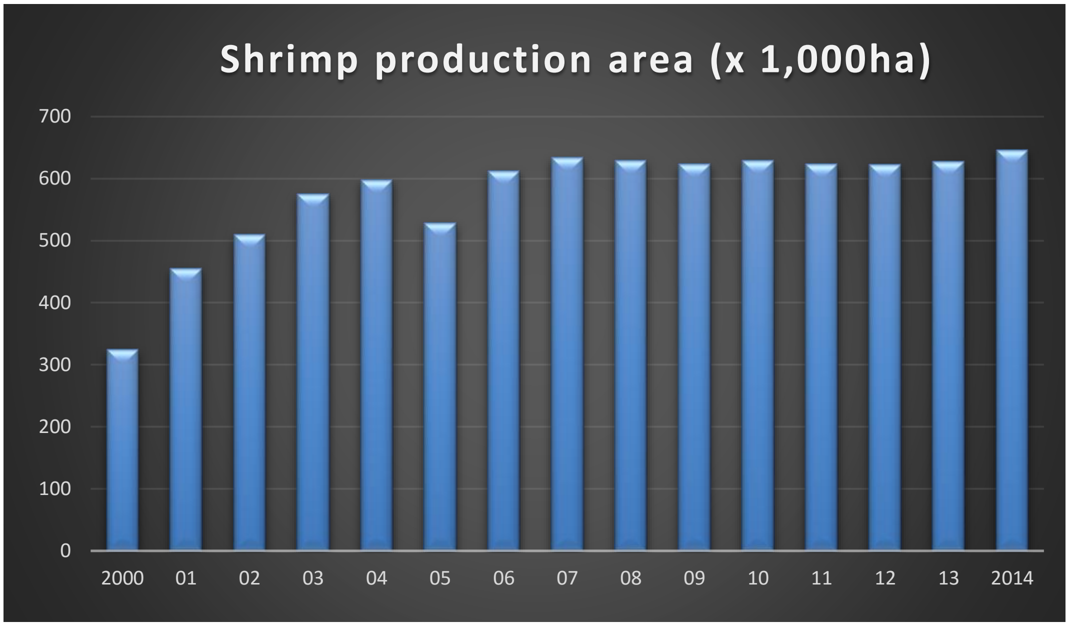


Figure 5. Total shrimp production area in Vietnam (Source: [VASEP 2014] [GSO 2016]).

This report assesses the three predominant production systems in Vietnam, including integrated shrimp-mangrove pond systems (i.e., silvofishery) and extensive ponds used for giant tiger prawn farming, and intensive ponds used for whiteleg shrimp. Production from more intensive farming, specifically for whiteleg shrimp, is increasing in Vietnam as the industry continues to develop better technology and expand infrastructure. According to the *Vietnam Aquaculture Plan (2010–2020)*, future expansion of the industry will not only entail expansion into new areas, but also the gradual reduction of extensive farming areas in favor of increased intensity (Corsin 2011). Communications with industry experts indicate that intensive and semi-intensive giant tiger prawn production have been almost completely replaced by the more intensive whiteleg shrimp farming (pers. comm., Luu 2014). Table 2 shows the percentage of production by species and production system in Vietnam; for the purposes of this report, semi-intensive and intensive whiteleg shrimp farming are considered together. Although integrated shrimp-mangrove farms are a type of extensive production system (Bosma et al. 2014), they are assessed separately in this report due to their unique silviculture component (i.e., mangrove cultivation integrated with shrimp farming).

Table 2. Percentage of production by species and production system in Vietnam (pers. comm., Luu 2014) (pers. comm., Fezzardi 2014).

POND SYSTEM	PRODUCTION (%)	
	Giant tiger prawn	***Whiteleg shrimp***
Intensive	-	60
Semi-intensive	10	40
Extensive	90	-
TOTAL	**100**	**100**

Extensive shrimp farming systems are characterized by large, earthen ponds located in rural coastal areas (Van Hao et al. 2003) (AAP 2013). Typically family-operated by local farmers, extensive shrimp farms are largely small-scale productions, and ponds average 2.5 ha in size or greater (Joffre et al. 2015) (Quoc 2016). Under this small-farm management system, extensive shrimp farming is considered to be low input and low output, where the degree of technology and control applied to ponds is restricted by low access to capital, and farmers are dependent on frequent exchanges with natural waterbodies to improve water quality (World Bank et al. 2006) (Joffre et al. 2015). One or two water sluices are used to control tidal water exchanges on a monthly basis (Minh et al. 2001) (Anh et al. 2010) (Joffre et al. 2015). Although the tidal influx from natural waterbodies has traditionally been used to passively supply shrimp stock (Van Hao et al. 2003), extensive shrimp ponds are now primarily stocked by hatcheries, and fertilizers are used to promote the growth of naturally occuring organisms in the water to accomodate the increased stocking density (World Bank 2010) (Hung and Quy 2013) (Bosma et al. 2014) (Ha et al. 2014) (Joffre 2015) (Quoc 2016). According to Le Dinh (pers. comm. 2017), nearly 100% of post larvae (PL) stocked are hatchery raised; to take into account environmental differences, this report estimates that 1% of PLs stocked are passively collected. These improved extensive systems account for 90% of the shrimp farming area in Vietnam (pers. comm., Bich 2013) (pers. comm., Luu 2013) (Thuy and Kager 2013) (Quoc 2016). A notable exception to this trend in system improvement is in the province of Ca Mau, where extensive systems do not generally use artificial seed and essentially follow organic or “natural” farming practices (Nair 2015). With a low survival rate of about 25%, only 250–600 kilograms (0.25-0.6 MT) of farmed shrimp are harvested per hectare over a typical year (Duijn et al. 2012) (Long et al. 2013) (Joffre et al. 2015) (Quoc 2016).

In the Mekong River Delta, extensive production systems are typically farmed by small farmers who raise high-value giant tiger prawn. Of the 337,614 households engaged in shrimp farming nationally, at least 80% are supplied by the Mekong River Delta region (Nair 2015) (GSO 2016) (Quoc 2016). These systems make up 90% of the total shrimp farming area and 60% of the production volume in this region (Joffre et al. 2015). In terms of land use, integrated shrimp-mangrove systems comprise 8.5% of the total shrimp farming area in the Mekong River Delta and 17.5% of the total shrimp farming area in Ca Mau Province (Joffre et al. 2015). For the 503,965 MT generated in 2014, the five leading provinces in the Mekong River Delta (and for Vietnam overall) were Ca Mau (149,005 MT), Bac Lieu (96,070 MT), Soc Trang (82,227 MT), Ben Tre (55,239 MT), and Kien Giang (51,430 MT) (GSO 2016).

Figure 6. Extensive shrimp farms in Vietnam (From [Auffrey 2011] [Mukhopadhyay 2014])

The integrated shrimp-mangrove (or silvofishery) system combines extensive shrimp farming with mangrove tree cultivation (Bosma et al. 2014). In these production systems, mangroves are either grown within the ponds or are planted on land within the farm boundary (Bush et al. 2010). With the fewest inputs of any shrimp culture system, this culture method is based on sourcing natural seed and food from adjacent waterbodies and culturing shrimp without chemicals or artificial aeration (Minh et al. 2001) (Quoc 2016). According to the literature, these systems rely on (passively collected) wild seed obtained from semimonthly water exchanges and use supplementary stocking to achieve a low stocking density of 1–3 postlarvae m^{-2} (Tho et al. 2011) (Joffre et al. 2015). In most cases, farmers harvest shrimp at each new moon, making the culture continuous (Bosma et al. 2014). These farms typically range in size from 5 to 15 ha (Joffre et al. 2015).

Although this culture system is practiced throughout Southeast Asia, integrated shrimp-mangrove farms in Vietnam are concentrated in Ca Mau Province (Joffre et al. 2015). In Ca Mau, provincial zoning regulations for mangrove cover have been established since 1999 (Minh et al. 2001). In its most current form, the legislation mandates that integrated shrimp-mangrove farmers must set aside 60% of their farm area (by tree-cover) for mangrove cultivation (IUCN 2013) (Nair 2015) (Van et al. 2015). Within this integrated shrimp-forestry system, mangroves are either planted within the pond or on bunds in and around ponds, are eventually harvested for timber, and then replanted for subsequent harvests (Joffre et al. 2015). These forestry requirements are managed and enforced by regional forestry management agencies in Ca Mau.

Extensive systems that integrate the cultivation of mangroves produce significantly lower yields (228–365 kg/ha/yr) than more intensive shrimp farming methods (Ha 2012) (Joffre et al. 2015), but their production involves much lower input costs and a much lower risk of crop failure from disease or pond pollution (IUCN 2013). Despite the advantages in reducing risks associated with shrimp culture and restoring important ecosystem services, integrated mangrove-shrimp systems are not widespread in the Mekong River Delta (Joffre et al. 2015). Furthermore, the income from improved, extensive, integrated mangrove-shrimp systems is insufficient to support farming expenditures and basic household living costs on a long-term basis (Minh et al. 2001).

Figure 7: Integrated shrimp-mangrove system in Ca Mau, Vietnam (Source: [Troell 2009] [VNN 2014])

Intensive shrimp pond systems are designed to maximize production by incorporating commercial feeds, chemical inputs, mechanical aeration, and hatchery-reared farm stock (Joffre et al. 2015). By using mechanical pumping, farmers can limit water exchanges with the surrounding environment to manage the water quality in the ponds and avoid the introduction of disease (Joffre and Bosma 2009). In Vietnam, intensive ponds are generally small in size (0.1–2 ha) (Duijn et al. 2012) (Long et al. 2013) (Tran et al. 2015) (Joffre et al. 2015) (Quoc 2016), rectangular (Tacon and McNeil 2004) (Gowing et al. 2006), and utilize two sluices for filling and draining (Van Hao et al. 2003). Intensive shrimp farms are being established especially in non-mangrove areas at higher elevations to allow the pond bottoms to dry completely between each production cycle (Ha 2012). Although whiteleg shrimp farms make up only 10% of the total shrimp farming area in Vietnam (Corsin 2011) (Tran et al. 2013) (Joffre et al. 2015) (Quoc 2016), intensive production is highly efficient (avg. 68% survival) and yields between 10 and 15 MT/ha after 90 to 100 days, with multiple crops possible per year (Gowing et al. 2006) (Duijn et al. 2012) (Tran et al. 2015) (Quoc 2016). Requiring a high degree of specialized managerial and technical support as well as advanced infrastructure, intensive systems need roughly 40 times the capital investment per hectare per year of extensive shrimp farming systems (Nair 2015). Under these circumstances, increasing system intensity remains cost-prohibitive for hundreds of thousands of small-scale farmers in Vietnam (GSO 2012).

Figure 8. Intensive shrimp farms in Vietnam. *(Source: BioAqua.vn 2014, Nhandan 2015)*

In summary, the scope of this assessment is giant tiger prawn farmed in integrated shrimp-mangrove and extensive pond systems, and whiteleg shrimp farmed in intensive ponds in Vietnam. Other terms used to describe shrimp farming in ponds include traditional (i.e., extensive) and nucleus-plasma (i.e., intensive) farming.

It should be noted that a relatively large number of shrimp farms in Vietnam have achieved third-party certification. This includes, as of August 2016, 41 Global Aquaculture Alliance Best Aquaculture Practices (GAA-BAP) certificates (a certificate may be issued to an individual farm or a collective of smaller farms, termed an Integrated Operating Module [IOM]) and 21 Aquaculture Stewardship Council (ASC) certificates (again, a certificate may encompass more than one farm). Additionally, several low-intensity farms have obtained Naturland certification, a European organic scheme. Although these and other international certification standards such as GLOBALG.A.P. are being actively promoted in Vietnam (Tran et al. 2015), the lack of reliable price premiums and problems with compliance in a fragmented supply chain have thus far inhibited widespread adoption of international voluntary standards among small-scale farmers (AAP 2012) (Nair 2015). A national voluntary certification scheme called VietGAP is also available to shrimp farmers.

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

- *Impact: poor data quality and availability limits the ability to assess and understand the impacts of aquaculture production. It also does not enable informed choices for seafood purchasers, nor enable businesses to be held accountable for their impacts.*
- *Sustainability unit: the ability to make a robust sustainability assessment*
- *Principle: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Criterion 1 Summary

Giant tiger prawn - Integrated shrimp-mangrove pond systems

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	5	5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	5	5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	2.5	2.5
Feed	No	Not relevant	n/a
Escapes, animal movements	Yes	5	5
Disease	Yes	5	5
Source of stock	Yes	2.5	2.5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**35**

C1 Data Final Score	**4.38**	**YELLOW**

Giant tiger prawn – Extensive pond systems

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	5	5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	5	5
Predators and wildlife	Yes	0	0
Chemical use	Yes	2.5	2.5
Feed	No	Not relevant	n/a
Escapes, animal movements	Yes	0	0
Disease	Yes	5	5
Source of stock	Yes	2.5	2.5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**27.5**

C1 Data Final Score	3.44	YELLOW

Whiteleg shrimp – Intensive pond systems

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	5	5
Effluent	Yes	5	5
Locations/habitats	Yes	5	5
Predators and wildlife	Yes	0	0
Chemical use	Yes	2.5	2.5
Feed	Yes	5	5
Escapes, animal movements	Yes	0	0
Disease	Yes	5	5
Source of stock	Yes	2.5	2.5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**30**

C1 Data Final Score	3.33	YELLOW

Brief Summary

For an industry as large and globally important as Vietnamese marine shrimp farming, data are surprisingly lacking. There is little of value published, in English, about key government agencies responsible for the regulation of marine shrimp farming, except for production data from the General Statistics Office of Vietnam's website. This report relies on a few leading studies into key issues of concern or into the particular production systems. These studies also tend to be based on quite small sample sizes (i.e., surveys of fewer than 70 farms). Additional information was also accessed by personal communication with industry experts. Slight differences in the data available between the production systems resulted in overall scores of 3.33 out of 10 for whiteleg shrimp, 4.38 out of 10 for integrated shrimp-mangrove systems, and 3.44 out of 10 for extensive giant tiger prawn systems for Criterion 1 – Data.

Justification of Ranking

Although the Vietnamese marine shrimp farming industry is of significant size and importance, there is poor availability of data. Key government agencies engaged in the regulation of marine shrimp farming, such as the Ministry of Agriculture and Rural Development (MARD), provide (in English) little more than news articles on their website (www.mard.gov.vn). There are three Research Institutes for Aquaculture (RIA), but only RIA-1 has a website (www.ria1.org). Regulatory information is also hard to find; broad-scope and sometimes-dated sources were relied on, such as the United Nations Food and Agriculture Organization (FAO) National Aquaculture Legislation Overview for Vietnam (cited in this report by its author: Murekezi 2014), though some regulatory information can be found in the published literature.

Recent (2014) production data by province are available from the General Statistics Office of Vietnam website (www.gso.gov.vn) but this was not broken down by species or by production system. This is considered moderate quality and a score of 5 out of 10.

Effluent data are limited for the extensive giant tiger prawn farming systems. But because they do not require additional feed and there are consistent conclusions regarding the (lack of) impact of fertilizer use, the data are considered sufficient for a complete and accurate assessment for this report. This results in a moderate-high score of 7.5 out of 10. For whiteleg shrimp, government monitoring data were unavailable, but the available literature, though dated, was useful in completing the calculations used in this report. This moderate data resulted in a score of 5 out of 10 for whiteleg shrimp.

Habitat impacts—specifically on the historical conversion of mangrove forests for shrimp farming—had a relatively high number of studies relevant to this assessment. The recent study by Son et al. (2015) was particularly useful in determining the ongoing conversion and restoration of mangrove habitats to and from the various shrimp production systems in Vietnam. The study by Vo et al. (2013) on legal compliance with mangrove coverage in the integrated shrimp-mangrove system was also important for this report. However, Le Dinh (pers. comm. 2017) considered further mangrove loss for shrimp farming unlikely. Despite these resources, the sheer number of farms in Vietnam means that the data quality can only be considered moderate for all systems, scoring 5 out of 10 for habitat data quality.

Data on chemical use were severely lacking, with conclusions in this report primarily being drawn based on two small (n = <75) farm surveys (one by Thuy et al. [2011] and another by Rico et al. [2013]) and a review by Uchida et al. (2016), which included results of a national testing program for antibiotic residue. Up-to-date information was available from the U.S. Food and Drug Administration (U.S. FDA) regarding current import rejections. Overall, the data for all systems are low-moderate, scoring 2.5 out of 10.

Since extensive systems do not generally use feed, data quality was not considered relevant to the assessments for giant tiger prawn. Intensive whiteleg shrimp systems do use feed, with data being available (but dated) on inclusion rates, FCRs, and protein content. No useable data were available on sources of wild fish used in feed. Whiteleg shrimp is given a moderate score of 5 out of 10 for feed data quality.

No information on escapes or their impacts could be found for Vietnam, resulting in a score of 0 out of 10 for whiteleg shrimp and extensive giant tiger prawn systems. Since integrated shrimp-mangrove systems use a significant amount of passive wild seed, the lack of data still allows for a moderate data quality score of 5 out of 10.

Current disease data at the national level are available from the World Organization for Animal Health (OIE); however, no specific information was available on impacts to wild populations, and the data were not broken down by species or production system. This resulted in a moderate data quality score of 5 out of 10.

Information on seed sources for giant tiger prawn were severely lacking, particularly regarding the status of wild broodstock fisheries. Limited information was available on the Chinese broodstock sources that supplied the majority of product to Vietnam. This resulted in a low-moderate score of 2.5 out of 10 for all production systems.

Data associated with predators and wildlife mortalities were generally quite limited for all systems in Vietnam, with some exceptions for the integrated shrimp-mangrove system. General information on shrimp farming practices had to be used for the assessment. For both whiteleg shrimp and extensive giant tiger prawn, the data score is 0 out of 10, and for integrated shrimp-mangrove systems, the data score is a low-moderate 2.5 out of 10.

Conclusion and Final Score

Overall, for an industry as large and globally important as the Vietnamese marine shrimp farming, data are surprisingly lacking. Though sufficient data were found to complete this report, it is largely based on a few key studies, personal communication with experts, and limited data available on government or international agency websites. Slight differences in the data available between the production systems resulted in overall scores of 3.33 out of 10 for whiteleg shrimp, 4.38 out of 10 for integrated shrimp-mangrove systems, and 3.44 out of 10 for extensive giant tiger prawn systems for Criterion 1 – Data.

Criterion 2: Effluent

Impact, unit of sustainability and principle

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: aquaculture operations minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.*

Criterion 2 Summary

Giant tiger prawn – Integrated shrimp-mangrove pond systems and extensive pond systems

Evidence-Based Assessment

C2 Effluent Final Score	**10.00**	**GREEN**

Whiteleg shrimp – Intensive pond systems

Risk-Based Assessment

Effluent parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N ton-1)	51.52		
F2.1b Waste discharged from farm (%)	10		
F2.1 Waste discharge score (0-10)		9	
F2.2a Content of regulations (0-5)	2.75		
F2.2b Enforcement of regulations (0-5)	0.5		
F2.2 Regulatory or management effectiveness score (0-10)		0.55	
C2 Effluent Final Score		**6.00**	**YELLOW**
Critical?	NO		

Brief Summary

The two main production systems for giant tiger prawn operate without the use of supplemental feed; although the extensive system may add fertilizer, it is insufficient to create a source of pollution. Thus, both systems were assessed using the Effluent Evidence-Based Assessment and found not to cause a concern to the environment, resulting in a score of 10 of 10 for Criterion 2 – Effluent.

Whiteleg shrimp farms are intensive and rely on additional feed, but fertilizers are rarely used. No effluent data are published for the Vietnamese whiteleg shrimp industry, so it was assessed using the Effluent Risk-Based Assessment methodology. Relatively low FCRs using high protein feeds resulted in a moderate 51.52 kg of nitrogen-based waste produced per ton of whiteleg shrimp. Waste released to the environment is further decreased by little to no exchange of water, except at harvest and proper sludge disposal; approximately 10%, or 5.15 kg N/t, is discharged from the farm, resulting in a score of 9 out of 10 for whiteleg shrimp for Factor 2.1. Regulation in Vietnam has been criticized for not responding quickly to the growth of the industry. Effluent regulations exist, including farm effluent water quality standards and regional water quality standards, but these are generally not applied during the permitting process because most new farms are below the size limit required for such measures. The results of regulatory monitoring were not forthcoming and data on pollution impacts were also scarce, but those that were available suggested that impacts were occurring. The lack of effective regulation and enforcement results in a score of 0.55 out of 10 for whiteleg shrimp for Factor 2.2. But the amount of waste discharged was very low, so the final score is 6 out of 10 for whiteleg shrimp for Criterion 2 – Effluent.

Justification of Ranking

Giant tiger prawn – Integrated and extensive pond systems

Integrated shrimp-mangrove systems are extensive and characterized by low inputs, which largely exclude both feed and fertilizers, and rely solely on the passive influx of nutrients from tidal exchanges to feed shrimp stock (Hanley 2007) (Ha et al. 2012) (Jonell and Henriksson 2014). With little or no external feed or fertilizer inputs, the nutrient loading in these ponds is low, and mangroves act as biofilters for pond effluents in these systems (Bush et al. 2010). Under these conditions, pond effluents often contain fewer nutrients than the inflowing tidal water relied on to exchange water (i.e., a net uptake of nutrients in ponds) (Anh et al. 2010) (Bosma and Verdegem 2011) (Jonell and Henriksson 2014).

Extensive shrimp farms are low-input systems that typically do not use feeds (Tacon et al. 2004) (Jory and Cabrera 2012) (White et al. 2013). Extensive shrimp farmers generally have little access to capital, and their ability to supplement production with feeds is strongly limited by their financial status and the high cost of commercial pellets (Joffre et al. 2015). In the absence of any feed inputs (Corsin 2011) (Bosma et al. 2014) (Joffre et al. 2015), giant tiger prawn farmed in extensive pond systems consume phytoplankton and zooplankton suspended in the pond water. Extensive shrimp farms can use fertilizers to promote the growth of naturally occuring organisms in the pond water to accomodate slightly higher stocking densities (World Bank 2010) (Bosma et al. 2014) (Ha et al. 2014) (Joffre 2015) (Quoc 2016). According to Tho et al. (2011) and Quoc (2016), inorganic urea and NPK (nitrogen, phosphorus, and potassium, provided in varying ratios) represent the two most widely used fertilizers in Vietnam. These fertilizers are applied at a rate of 40 to 60 kg ha^{-1} (Hung and Huy 2007) and produce shrimp yields ranging from 250 to 500 kg ha^{-1} (Ha and Bush 2010) (Hai et al. 2014) (Quach and Morrison-Saunders 2015). Based on the median of these values, a total fertilizer input of 133.3 kg per ton of shrimp was calculated using an average fertilizer application rate of 50 kg ha^{-1} and a giant tiger prawn production yield of 375 kg ha^{-1}. Calculations for the nitrogen component of total fertilizer inputs are based on FAO specifications for inorganic urea (46% N) and NPK fertilizer (18% N) (Hung and Huy 2007). Using an average fertilizer nitrogen content of 32%, the fertilizer nitrogen input per ton of shrimp produced is 42.66 kg, leading to an overall nitrogen-based waste production level of 14.19 kg per ton of giant tiger prawn farmed in extensive ponds. But there is a general consensus among recent research, such as (Anh et al. 2010) (Tho et al. 2013), that extensive forms of shrimp culture in Vietnam are not major sources of pollution.

Because both giant tiger prawn production systems do not use feed and do not use fertilizers to the degree sufficient to cause pollution, they were assessed using the Evidence-Based Assessment method in the Seafood Watch Aquaculture Standard. The lack of feed and fertilizer inputs (as the dominant source of nutrient waste outputs) means that the effluent is not considered a concern for either giant tiger prawn production system.

For giant tiger prawn, the final score is 10 out of 10 for Criterion 2 – Effluent.

Whiteleg shrimp – Intensive pond systems

Whiteleg shrimp farming in Vietnam is intensive. This type of production system has developed rapidly on a global scale and faces a number of issues relating to discharged waste, including water intake and outputs to the same waterbody (self-pollution), cumulative pollution from multiple farms in the region, and impacts to the coastal environment (White et al. 2013). The high stocking densities and feed inputs used in the ponds reduce water quality, and discharged effluents have the potential to affect rivers and coastal habitats in the surrounding environment (Nair 2015). But without robust research that has demonstrated or quantified such coastal impact, whiteleg shrimp farming was assessed using the Risk-Based Assessment method. The ratings provided below for Factors 2.1 and 2.2 apply to whiteleg shrimp only.

Factor 2.1a – Biological waste production per ton of shrimp

<u>Factor 2.1a – Biological waste production</u>

The Risk-Based Assessment estimates the amount of waste nitrogen produced per ton of whiteleg shrimp farmed.

Shrimp excrete waste primarily as a result of incomplete digestion and absorption of their feeds, and only a small portion of the nutrients in the feed are consumed, assimilated, and retained for tissue growth. Early research by Briggs and Funge-Smith (1994) and Green et al. (1997) indicated that only 24%–37% of the nitrogen and 13%–20% of the phosphorus from feed was retained by shrimp. Similarly, Lorenzen (1999) also reported that 20%–40% of the fed nitrogen was incorporated into shrimp tissue. The remaining wastes that are present in the water column or as settled solids promote eutrophication in the pond system as well as in neighboring waters upon their release from the farm site (Davis et al. 2006).

Fertilizers are rarely used in intensive farming because the shrimp receive all their nutritional needs from the commercial feed, and fertilizer inputs would only worsen water quality conditions (Hung and Quy 2013). In Vietnam, feeds contain high protein levels ranging from 36% to 44% (Hung and Quy 2013). Reported feed conversion ratios (FCR) for intensively farmed whiteleg shrimp vary from 1.1 to 1.4 (VDoA 2008) (Hung and Quy 2013) (Long et al. 2013) (pers.

comm., Micciche 2013) (Quoc 2016). Based on these data sources, an average economic FCR (eFCR) value of 1.25 and a 40% protein content of feed are used in this assessment. Based on research by Boyd (2007), the protein content of whole, harvested, farmed shrimp is considered to be 17.8%. These values result in an estimated 51.52 kg of nitrogen-based waste produced per ton of whiteleg shrimp.

Factor 2.1b – Production system discharge

The introduction of whiteleg shrimp into Vietnamese aquaculture prompted a move toward intensive culture systems with limited water exchange (Briggs et al. 2004) (Lan 2013) (Nair 2015) (Tran et al. 2015). Although a 2010 report by Anh et al. indicates a daily water exchange rate of 1%–1.5% of pond volume, more recent data indicate that there is little or no water exchange in intensive production systems (i.e., water may be exchanged if nutrient loads are high in the last month of culture) (Ha 2012) (pers. comm., Luu 2014), and intensive systems typically use aerators and water pumps rather than water exchanges to maintain water quality (pers. comm., Lee 2014). For these reasons, a basic (unadjusted) production system discharge score of 0.34 was used (i.e., a pond system discharging once per cycle during harvest). This score can be adjusted where suitable effluent treatment systems are applied.

In Vietnam, national legislation established in 2010[1] encourages intensive shrimp farmers to build effluent treatment systems, but current costs and the lack of available land prohibit the large-scale adoption of treatment ponds, and few shrimp farms carry out water or sediment treatment (Anh et al., 2010). According to Nair (2015), intensive farms often discharge pond effluent into the rivers and canal systems without proper treatment. Furthermore, when intensive shrimp farms are located in areas with acid sulfate soils (common to mangrove areas), ponds may be filled and flushed an additional 3 or 4 times before being restocked (Anh et al. 2010). For small-scale producers, clean water is often pumped into ponds to flush out sediments and then pumped back into waterways (pers. comm., Luu 2014).

Sludge in shrimp ponds is generated by several sources, including uneaten feed, feces, shrimp shells, dead shrimp, organic material introduced from water exchanges, and inorganic matter eroded from pond walls and dikes (Briggs and Funge-Smith 1994). The national legislation established in 2010[2] also requires intensive shrimp farmers to build robust storage areas for pond sludge treatment, and an industry expert indicates that many of the larger producers transfer sludge material to tilapia ponds (pers. comm., Luu 2014).

---

[1] Circular No. 4512010rrT-BNNPTNT 2010, Ch 2, Article 4, 2b: Wastewater treatment systems: Shrimp rearing establishments and zones are encouraged to build systems for treatment of wastewater from shrimp ponds before discharge into the environment.

[2] Circular No. 4512010rrT-BNNPTNT 2010, Ch 2, Article 4, 2c: Waste mud storage areas: Shrimp rearing establishments and zones must build waste mud storage areas for treatment of all waste mud volumes after each farming drive and waste mud storage areas must be built with walls to prevent mud and mud-water from penetrating into the surrounding environment. Ch 2, Article 6, 5d: Solid wastes and pond-bed mud must be stored in separate areas and not be discharged into the surrounding environment when they are not yet treated.

Though full effluent treatment systems may be uncommon, an adjustment of –0.24 is applied for proper sludge disposal and results in an adjusted Factor 2.1b score of 0.1, which means that 10% of the waste produced by the shrimp is discharged from the farm.

The waste production and discharge values of Factor 2.1a and Factor 2.1b are multiplied to give an estimated discharge from the farm of 5.15 kg N/t of whiteleg shrimp. This value equates to a score of 9 out of 10 for whiteleg shrimp for Factor 2.1.

Factor 2.2a – Content of effluent regulations and management measures
In this factor, effluent regulations at the national level are used to assess how discharged wastes from shrimp farms are being managed from a regulatory perspective. Although some of the following regulations are not species-specific or production intensity-specific to shrimp aquaculture, the scores only pertain to whiteleg shrimp because effluent from the giant tiger prawn production systems is not considered to have an effect.

Aquaculture regulation and planning in Vietnam has been criticized as being too slow, resulting in negative impacts on the environment (Nhuong et al. 2002) and leading to a decline in coastal aquatic resources (Nga 2008). This is reflected by aquaculture's inclusion in Vietnam's Fisheries Law for the first time in 2003. This law has no legal definition for aquaculture practices, only two separate distinctions between "aquaculture land" (including coastal and inland areas) and "marine areas for aquaculture" (referring to sea areas used for aquaculture) (Murekezi 2014). Prior to its inclusion in the Fisheries Law, aquaculture was controlled by the requirement for an environmental impact assessment (EIA) established in a 1994 revision of the Law on Environmental Protection established in 1993 (Philips et al. 2009). Coastal zone planning in Vietnam was described by World Bank (2005) as "ad hoc," approved based on budget, and "in many cases ignoring boundary issues, negative environmental impacts or the interests of other stakeholders."

Under the Fisheries Law of 2003, a certificate to use any specific area for aquaculture purposes must be obtained (Murekezi 2014). All shrimp aquaculture covered in this report would be considered under the "aquaculture land" requirements, and would be subject to Vietnam's Law on Land requirements, specifically Article 13 (Murekezi 2014). The Law on Land combines a master zoning plan with specific controls for the allocation of land (Murekezi 2014). Relevant controls for coastal shrimp aquaculture include (Murekezi 2014):

- A defined administrative process for applying for a lease.
- Limits to the length of a lease (20 years for individuals and households, 50 years for economic organizations and 70 years for large projects with a low rate of return or that focus on areas with socioeconomic difficulties).
- Limiting individuals and households to a maximum leasable area of 3 ha.
- Establishing state control of coastal land.
- Requiring that aquaculture leases are confined to approved zones and land use plans.
- Protecting the ecosystem, environment, and landscape.

Several governmental groups are involved in the authorization process for an aquaculture lease, including local government "People's Committees," regional offices of the Natural Resources and Environment Sections, the state-level Ministry of Natural Resources and Environment (MONRE), and the Ministry of Agriculture and Rural Development (MARD) (Murekezi 2014).

According to Murekezi (2014), the relevant administrative requirements for individuals and national organizations to obtain an aquaculture lease include:
"1. an application letter for lease of the area for aquacultural purposes, certified by the People's Committee and including a statement of skills and commitments to protect the environment;
2. a feasibility study on aquaculture appraised by the fisheries agency at the provincial level;
3. the justification of technical capacity on aquaculture;
4. an Environmental Impact Assessment (EIA) on aquaculture and an environmental protection plan appraised by the management agency dealing with the environment."

The relevant administrative requirements for individuals and foreign organizations to obtain an aquaculture lease include (Murekezi 2014):
"1. an application letter for lease of the area for aquacultural purposes certified by the People's Committee and including a statement of skills and commitments to protect the environment;
2. an Environmental Impact Assessment (EIA) on aquaculture and an environmental protection plan appraised by the management agency dealing with the environment."

Leases can be revoked by the State if any of the following apply (Murekezi 2014):

- "the marine area is misused;
- the marine area has not been used continuously for 24 months except for proper reasons accepted by competent State agencies;
- the users of marine areas for aquaculture do not fully comply with the obligations established in the Aquaculture Chapter of Viet Nam's Fisheries Law;
- the users of marine areas for aquaculture voluntarily return the allocated or leased areas; or
- the State needs to revoke for public security and national defence purposes."

EIAs are required to forecast environmental impacts, include mitigation measures, and have specific environmental protection commitments (Murekezi 2014). These commitments must include the following (Murekezi 2014):
"1. the location of the execution of the project;
2. the type and scale of production, business or service, and materials and fuel used;
3. the kind of wastes generated; and
4. the commitment to apply measures to minimize and treat wastes and to strictly comply with the provisions of the Law on Environmental Protection."

Despite these legal controls, Philips et al. (2009) reported that only a small number of complete EIAs are actually being undertaken, due to the small-scale nature of the industry. For example, Decree No. 29/2011/ND-CP of April 18, 2011 states that actual reporting on an EIA is only required for three types of aquaculture; specifically (FAO 2011):

- Intensive or semi-intensive aquaculture with a water surface area of 10 ha or larger
- Extensive aquaculture with a water surface area of 50 ha or larger
- Aquaculture built on sand with a rearing area of 10 ha or establishments larger

Nevertheless, according to Murekezi (2014), the Law states that "household-based production, business, or service establishments and entities that are not required to complete environmental assessment reports or environmental impact assessment reports must make written environmental protection commitments."

Aquaculture effluents are not specifically addressed in the Fisheries Law but are covered under the Law on Environmental Protection and the Law on Water Resources; these Laws require that farms collect and treat wastes according to environmental and waste standards, and that wastes cannot be dumped into national waters (Murekezi 2014). A wastewater discharge permit is required for all operations except small-scale family operations (Murekezi 2014).

According to Murekezi (2014), the producer must provide details on the parameters and concentrations of pollutants in wastewater, environmental quality standards for the water sources receiving wastewater, a plan on supervision and observation of quality of water sources receiving wastewater, and a plan for minimizing pollution. The regulator then decides if a permit can be issued (MNRE 2005). Circular No. 4512010rrT-BNNPTNT of July 22, 2010 outlines specific requirements for intensive giant tiger prawn and whiteleg shrimp farms (excluding semi-intensive or extensive production) and zones on the basis of hygiene and food safety (VLLF 2010). It "encourages" farms to build wastewater treatment systems and requires them to meet effluent quality standards outlined in Table 3 (VLLF 2010).

Table 3. Effluent water quality standards for intensive giant tiger prawn and whiteleg shrimp farms in Vietnam (copied from VLLF 2010).

No.	Norm	Unit	Permitted limit
1	BOD_5	mg/l	< 30
2	NH_3	mg/l	< 0.3
3	H_2S	mg/l	< 0.05
4	NO_2	mg/l	< 0.35
5	pH		6 ÷ 9
6	Temperature	^0C	18 ÷ 33
7	Specific gravity	%0	5 ÷ 35
8	Dissolving oxygen (DO)	mg/l	≥ 3.0
9	Clarity	cm	20 ÷ 50
10	Alkaline	mg/l	60 ÷ 180

Philips et al. (2009) reported that Vietnam also sets regional environmental quality standards that are monitored by MARD using four regional Research Institutes for Aquaculture (RIA), which also monitor for disease. According to Philips et al. (2009):

- "RIA No 1 is in charge of monitoring of environment and disease for six provinces from Haiphong to Thua Thien – Hue with an emphasis on areas with concentrated aquaculture development.
- RIA No 2 is in charge of monitoring of environment and disease at aquaculture areas of Mekong delta provinces from Ca Mau to Ho Chi Minh City, including Ba Ria – Vung Tau provinces.
- RIA No 3 is in charge of monitoring of environment and disease at aquaculture areas of central provinces from Da Nang to Binh Thuan province in concentrated aquaculture areas.
- RIMF is in charge of monitoring of environment and biodiversity of marine aquaculture areas, fish ports from Quang Ninh – Haiphong to Tra Vinh and four marine protected areas (Cat Ba, Bach Long Vy, Con Co and Phu Quoc)."

Philips et al. (2009) reported that there is limited consistency between the monitoring activities of each EIA; key environmental quality standards (EQS) that have been agreed to are listed in Table 4.

Table 4. Agreed environmental quality standards by Research Institutes for Aquaculture in Vietnam (copied from Philips et al. 2009).

Monitoring parameters for coastal aquaculture

Parameter	Unit	Range or maximum permitted values (where provided)	Analytical method
1. pH	-	6.5–9.0	pH meter
2. Dissolved oxygen (DO)	mg/l	4–8	
3. Biochemical oxygen demand (BOD)	mg/l	20	azide modification by synthetic seawater
4. Chemical oxygen demand (COD)			Potassium permanganate ($KMnO_4$)
5. Suspended solids (SS)	mg/l	70	Filtration using glass fibre filter disc
6. NO_2-N	mgN/l	0–0.005	SMEWW(Standard Methods, 2006) 4500-NO2-B
7. NO_3-N	mgN/l		Cadmium reduction method
8. NH_3-N (ammonia nitrogen)	mgN/l	<0.02 (as NH_3)	SMEWW 4500-NH3
9. Total phosphorus	mgP/l	0.4	Ascorbic acid
10. Total nitrogen	mgN/l		TCVN 5987 – 1995
11. H_2S (hydrogen sulfide)	mg/l	0.01	Methylene blue
12. Oil	mg/l		TCVN 5070 – 1995
13. *Vibrio* spp			Total plate counts
14. Algae			
15. Pesticides			HPLC
16. Heavy metals			Atomic absorption spectrometry

Another difference between each RIA is their frequency of monitoring. Philips et al. (2009) reported the following:

"RIMF: minimum of two times a year in selected locations, once in the dry and once in the rainy season. One time per year for corals and marine protected areas (MPA).
RIA-3: Five times a year in February, April, June, August and November
RIA-1: No regular monitoring because of limited budgets, but monitoring carried out depending on budget from March to August every year.
RIA-2: Automatic sampling stations for pH, DO in every 2–3 hours in selected locations. Other environment parameters every three months. Aquatic animal disease sampling planned for every two months."

Both Tables 3 and 4 show that Vietnam's water quality standards are comparable to the requirements of the Global Aquaculture Alliances Best Aquaculture Practices (BAP) Effluent Water Quality Criteria shown in Table 5, suggesting a high degree of applicability to the industry.

Table 5. BAP Effluent Water Quality Criteria - All Pond Farms. From BAP (2014)

	Initial Value	Final (after 5 Years)	Collection Frequency
pH (standard pH units)	6.0-9.5	6.0–9.0	Monthly
Total suspended solids (mg/L)	50 or less	25 or less	Quarterly
Soluble phosphorus (mg/L)	0.5 or less	0.3 or less	Monthly
Total ammonia nitrogen (mg/L)	5 or less	3 or less	Monthly

5-day biochemical oxygen demand (mg/L)	50 or less	30 or less	Quarterly
Dissolved oxygen (mg/L)	4 or more	5 or more	Monthly
Chloride	No discharge above 800 mg/L chloride into freshwater	No discharge above 550 mg/L chloride into freshwater	Monthly

The above information was used to score Factor 2.2a Regulatory or management effectiveness; effluent regulations that are applicable to aquaculture exist and are applicable to aquaculture, resulting in a score of 1. The permit process is scoped at the farm level but a common set of effluent quality standards exist, which means that the discharge limits are not site-specific, which resulted in a score of 0.75. Because regional water-quality standards are used but are monitored infrequently, a moderate score of 0.5 was given regarding the control measures for the cumulative impact of multiple farms. The limits used in Tables 3 and 4 have some consistency with aquaculture-specific limits used by BAP in Table 5, but there is no clear reference to these being set according to the ecological status of receiving waters, resulting in a moderate score of 0.5. There is no evidence to suggest that the control measures for effluents cover all aspects of the production cycle, which results in a score of 0. Combined, this results in a score of 2.75 out of 5 for Factor 2.2a.

Factor 2.2b – **Enforcement of effluent management measures**
According to its website, MARD has the mandate to "issue, monitor, inspect implementation of national technical standards" (MARD 2016). No specific information was available to determine whether MARD currently has the resources to regulate the scale of the industry, but Philips et al. (2009) found that provincial environmental authorities lacked sufficient facilities, laboratories, and suitable staff to effectively monitor aquaculture, suggesting that current systems are unlikely to be appropriate to the scale of the industry. No regulatory effluent monitoring data were found for any type of shrimp farming system in Vietnam, and there is no evidence to suggest that the monitoring frequency is aligned with harvest periods. Of the RIAs, only RIA-1 has an accessible website, but it does not report the results of EQS monitoring. No specific reports could be found of enforcement or robust penalties for infringements. Several studies reported excessive pollution impacts for shrimp farms in Vietnam including:

1. Anh et al. (2010) studied water pollution from intensive shrimp farming in the Can Gio district of Ho Chin Minh City, finding that "while a large number of individual farms may exceed environmental standards, intensive shrimp farming is not always associated with waste streams exceeding water quality standards."
2. Thuyet (2012) concluded "Spatial variation was found with high levels of nutrient and nutrient-related parameters (dissolved inorganic nitrogen, total phosphorus, biochemical oxygen demand, chlorophyll-a in water; total nitrogen, total phosphorus, total organic carbon in sediment) at channels/creeks adjacent to shrimp farms with these levels declining in the same creeks 2 - 3 km away from the effluent discharged points. In addition, water quality was found to vary temporally with nutrient levels elevated after shrimp crops, especially for sampling sites adjacent to shrimp farms."

3. Lan (2013) reported that “Effluence including chemical inputs and waste from shrimp farming ponds are often released directly into the natural environment without any treatment, even in the case of shrimp disease outbreaks. This is a direct source of contamination to soil, rivers and coastal habitats.”

Of the questions in Factor 2.2b enforcement of effluent regulations or management, only question 1 received a score above 0. A moderate (0.5 out of 1) score was given because MARD can be identified and contacted, but there is also evidence to suggest that it is unable to enforce regulations across the whole industry.

The score for Factor 2.2a is multiplied by Factor 2.2b and then divided by 2.5 to give a total score for Factor 2.2 of 0.55 out of 10 for whiteleg shrimp.

Conclusions and Final Score

There is no use of feed in extensive or integrated shrimp-mangrove systems used to farm giant tiger prawns, so effluent is not considered a concern and the final score is 10 out of 10 for Criterion 2 – Effluent. Whiteleg shrimp farming produces a moderate amount of waste, but little is actually discharged into the surrounding environment, thus reducing the risk of pollution from effluents. Effluent regulation exists, with environmental quality standards that are relevant to aquaculture, but there is insufficient evidence that it is either complete or effective, with several reported incidents of impacts associated with shrimp farm effluent. The scores for Factors 2.1 and 2.2 are combined using the Risk-Based Assessment matrix, resulting in a final score of 6 out of 10 for whiteleg shrimp on Criterion 2 – Effluent.

Criterion 3: Habitat

Impact, unit of sustainability and principle

- *Impact: Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats and to the critical "ecosystem services" they provide.*
- *Sustainability unit: The ability to maintain the critical ecosystem services relevant to the habitat type.*
- *Principle: aquaculture operations are located at sites, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats.*

Criterion 3 Summary

All species and production systems

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		1.00	
F3.2a Content of habitat regulations	1.75		
F3.2b Enforcement of habitat regulations	2.00		
F3.2 Regulatory or management effectiveness score		1.40	
C3 Habitat Final Score		**1.13**	**RED**
Critical?	NO		

Brief Summary

Globally, shrimp farming has been linked to the historical conversion of ecologically important wetlands, including mangrove forests. Vietnam is no exception, with two-thirds of the country's forests converted for aquaculture between 1980 and 2000. These losses were exacerbated by the disturbance of acid soils created during pond construction, which in some cases created extreme acidification, damaged remaining mangroves, and resulted in ponds being abandoned, with new areas cleared for new ponds. Recent studies indicate a moving picture of both conversion and restoration to and from all three production systems assessed in this report, with one reviewer suggesting that further losses were unlikely. Because the weight of evidence demonstrates recent (but not necessarily widespread) ongoing conversion of high value habitats, the score for Factor 3.1 for all production systems is 3 out of 10. Integrated shrimp-mangrove systems are legally required to maintain 60% mangrove coverage and should be eligible for a much higher score (7 out of 10), but the available evidence suggests that the law is not being enforced; mangrove coverage is generally much lower (≈30%). In addition, the mangroves are considered a harvestable crop and a single species is planted (rather than multiple species, which are found in virgin habitat), which results in their ecosystem services being significantly less than those of undisturbed mangrove forests. Given that mangroves have recently been converted to build this type of farm, integrated shrimp-mangrove systems also receive a score of 1 out of 10 for Factor 3.1.

All the production systems were considered together regarding habitat management. Low scores were given primarily as a result of the promotion of shrimp farming over habitat protections, especially at the local government level. Historically, regulation has been slow to address the growth of the industry and, although current regulations exist (including EIAs that include public engagement), they only apply to large farms and not the smaller farms that make up the majority of the industry. Data are also lacking on enforcement, but a key example of its failure is the inability to enforce the 60% mangrove coverage rules in the integrated shrimp-mangrove systems. There is potential for improvement in the future, particularly through a World Bank project including integrated spatial planning of all coastal areas and across sectors. Factor 3.2 was scored as 1.4 out of 10 for all production systems.

Overall, the combination of recent critical habitat losses with insufficient enforcement of regulation gives a final Criterion 3 – Habitat numerical score of 1.13 out of 10 for all production systems. It should be noted that suitable verification of legal compliance would be sufficient to obtain a higher habitat score for all production systems, particularly the integrated shrimp-mangrove system.

Justification of Ranking

Factor 3.1. Habitat conversion and function

All the production systems assessed in this report have affected mangrove forests to varying degrees. The issues are discussed in general first because they apply to all systems, and the differences for integrated-mangrove systems are discussed subsequently.

The importance of mangroves for ecosystem services has been widely documented (Primavera 1998). Mangrove forests are among the most productive and biologically complex ecosystems in the world and play a major role in the protection of coastal communities against natural disasters, prevent erosion and the release of acid-sulfate soils, serve as nurseries for native shrimp (and other species), and mitigate greenhouse gas emissions (Alongi 2008) (Barbier et al. 2008) (Hussain and Badola 2010) (McNally et al. 2011) (Parr 2013) (Vo et al. 2013).

Since the 1980s, the Vietnamese government has actively encouraged shrimp farming for export, and the industry's development has largely been at the expense of mangrove forests, especially in southern Vietnam (Hong and San 1993) (Nhuong et al. 2002). From the 1980s to the late 1990s, rapid expansion of the shrimp farming industry throughout most of the Mekong River Delta was further driven by economic liberalization policies, high international prices, and promotion by international organizations, such as the World Bank and the Asian Development Bank (Hong and San 1993) (Hashimoto 2001) (Binh et al. 2005). It was estimated that 102,000 ha of mangroves were converted into shrimp farms between 1983 and 1987 (Tuan 1996, cited in Stevenson 1997).

By 2000, approximately two-thirds of Vietnam's remaining mangroves had been converted by the development of the aquaculture sector (IUCN 2012) (Van et al. 2015), and shrimp farming specifically was a major cause of mangrove loss throughout the country (Giesen et al. 2006) (Nga and Tinh 2008). Of the 235,000 ha of shrimp farms added between 2000 and 2001, 232,000 ha were converted from rice paddies, 1,900 ha from saltpans, and only 1,200 ha from mangrove forests (Omoto 2012). Surveys by Lebel et al. (2002) in southern Vietnam (Ca Mau) also found that 50% of the shrimp farms were converted from rice paddies, whereas in northern Vietnam most of the shrimp ponds were previously mangroves.

A study by Son et al. (2015) using satellite data to assess mangrove losses shows net conversion of mangrove forest to shrimp aquaculture between 2003 and 2013 decreased to just 3,300 ha. But this small loss masked the conversion of ≈8,500 ha of mangrove forest to mixed aquaculture mangrove uses (a.k.a., integrated shrimp-mangrove systems) and ≈6,150 ha of mangrove forests to straight aquaculture, which were offset by the reforestation of ≈10,000 ha of mixed mangrove and ≈2,300 ha of aquaculture-only ponds systems back to mangrove forests (Son et al. 2015). Details of the conversion or restoration were not provided, so this report assumes that, in the case of integrated systems, undisturbed mangroves were cleared and re-planted with monoculture, and assumes that the effectiveness of any restoration efforts is unknown. Any evidence of further conversion of forest to any type of shrimp pond system is important, because an additional consequence of the conversion of mangrove forests to shrimp farms is the acidification of soils within shrimp farms and in the surrounding area. It is unknown if the acidification inhibits mangrove reforestation efforts.

Mangroves require soils that contain metal sulphides (inactivated acid sulfate soils). Although these soils pose little or no risk if undisturbed, acid-sulphate soils undergo oxidation once disturbed by pond construction. This can lead to acid pollution and damage to mangroves outside the immediate farm area (Davenport et al. 2003). In Vietnam, mangrove areas with acid sulphate soil cover about 1.8 million ha, most of them occurring in the Mekong River Delta. Shrimp pond construction in the Delta has historically disturbed these soils and resulted in severe acidification throughout the region (Van Wijk 1999). This has directly led to shrimp pond abandonment and the successive expansion of the industry into new areas once ponds become acidic (Hens et al. 2009).

Figure 9 shows the areas of mangrove forest converted to various other states and those reforested from aquaculture between 2003 and 2013 in southern Vietnam (from Son et al. 2015). Besides a concentrated area of reforestation from brackish water aquaculture, there is no apparent pattern to the distribution of conversion and reforestation of the integrated shrimp-mangrove systems.

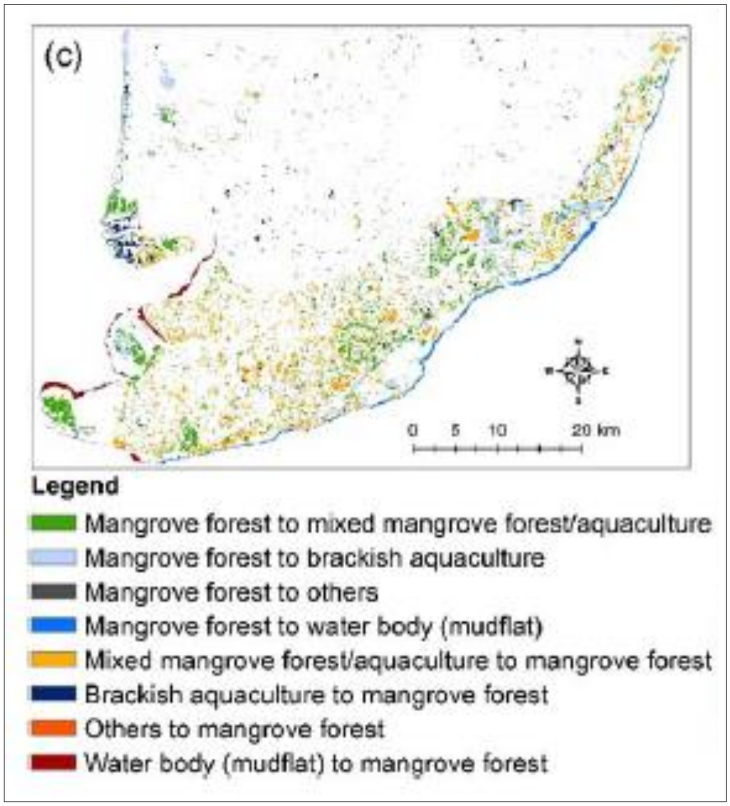


Figure 9. Conversion and restoration of mangrove forest for shrimp farming by production system in Southern Vietnam between 2003 and 2013 (copied from Son et al. 2013).

Some personal communication with local experts has indicated that further mangrove loss in Vietnam to shrimp farming was unlikely (pers. comm., Le Dinh 2017)—especially given legal requirements such as Decree 186, which encourages ongoing restoration where mangroves where once lost.

In summary, there is evidence of significant historic losses of ecologically important mangrove forest habitat associated with all types of shrimp aquaculture in Vietnam. Though the rate of loss has declined sharply, recent studies point to quite recent, but not necessarily ongoing, conversion of forest to all types of shrimp farming, potentially including undisturbed mangroves with negative ecosystem impacts caused by acid pollution. This results in a score of 1 out of 10 for Factor 3.1 Habitat conversion and function for both extensive giant tiger prawn and intensive whiteleg shrimp farming.

<u>Giant tiger prawn, integrated shrimp-mangrove systems</u>
Integrated shrimp-mangrove systems have the potential for a different rating by virtue of including mangroves in the pond designs, which may serve to retain some of the ecosystem services that could have been provided by undisturbed forests. This is one of the main reasons that these systems have been promoted since 1978 (Tran 2005) (Ha et al. 2012a). Importantly, mangroves also act as a natural filtration system for integrated shrimp-mangrove farms, which

in turn reduces disease impacts and improves water quality in ponds (Tendencia et al. 2012) (IUCN 2013) (Nair 2015).

Integrated shrimp-mangrove farms in Vietnam are concentrated in Ca Mau Province, while the number of integrated shrimp-mangrove systems in other provinces of the Mekong Delta is negligible (Joffre et al. 2015). More than 90% of integrated shrimp-mangrove farms are contracted by either a State Forest Enterprise or Forest Management Board, which stipulate a specific forest-to-pond area ratio (Ha et al. 2014) (Joffre et al. 2015). In Ca Mau, provincial zoning regulations for mangrove cover have been established since 1999 (Minh et al. 2001) and, in their most current iteration, mandate that integrated shrimp-mangrove farmers in the Buffer Zone (0.5-4 km inland from a coastal greenbelt known as the Full Protection Zone) set aside 60% of their farm area by tree-cover for mangrove cultivation (IUCN 2013) (Vo et al. 2013) (Nair 2015) (Van et al. 2015). This is important to note because SFW considers the retention of 50%–70% mangrove forest to only be moderately affected, potentially scoring as high as 7 out of 10 for Factor 3.1. But two issues rule this out. The first, which is discussed further in Factor 3.2, is that the 60% mangrove coverage rule is not being followed, with a significant number of farms having less than 30% coverage (Vo et al. 2013), and the second, discussed below, is the degree to which the mangroves in the integrated shrimp systems provide ecosystem services.

Within integrated shrimp-mangrove systems, the mangroves are either planted within the pond or on dikes in and around ponds (Joffre et al. 2015); the latter being the most common configuration (Bosma et al. 2014). Despite the mandatory level of mangrove cover, farmers are actually allowed to harvest the mangroves (Nair 2015). The degree to which the integrated shrimp-mangrove systems contribute to ecosystem services depends on their connectivity with the surrounding aquatic environment and on several hydrological and topographic factors (Zavalloni et al. 2014). Given the water retention in integrated shrimp ponds, Clough et al. (2002) indicate that "…normal tidal flooding and flushing is prevented by the more or less constant water level in the pond." Moreover, the mangrove trees growing on top of dikes are disconnected from aquatic resources in the pond and have little connectivity with other habitats and ecosystem services beyond the farm boundary (e.g., nutrient cycling and biodiversity) (Bosma et al. 2014).

Another key weakness with the integrated shrimp-mangrove farms is the frequent planting of a single, homogeneous mangrove species. The majority of the new mangrove cover in integrated shrimp farms is *R. apiculata* because of its high timber value and simplicity in planting (Hong 2003) (Goessens et al. 2014). Although planting mangroves in monoculture qualifies shrimp farmers who are aiming to meet regulatory requirements, this type of "utility" planting gives little consideration for the maintenance of ecosystem services and does not provide the full range of ecosystem functionality established by the faunistic composition or structural complexity present in natural mangrove ecosystems (IUCN 2012) (Van et al., 2015).

There is published evidence that the legal requirement of 60% mangrove coverage is not generally being conformed to and the mangroves present are unlikely to provide ecosystem services beyond the farm itself, so under Seafood Watch criteria, this is considered a major impact with loss of functionality. Although personal communication with a local expert indicates that legal compliance may be rising (pers. comm., Le Dinh 2017), the weight of published evidence indicates that, broadly, the design and operation of integrated shrimp-mangrove systems are not providing the ecosystem services they are capable of. Ultimately, there is insufficient evidence to warrant an increased score for these systems, so the score of 1 out of 10 is applied to all shrimp production systems in Vietnam. It should be noted that suitable verification of legal compliance would be sufficient to obtain a significantly higher habitat score for integrated shrimp-mangrove systems.

Factor 3.2. Habitat and farm siting management effectiveness

Since Factor 3.2 assesses both previous siting controls as well as future expansion, all three production systems are considered together.

Factor 3.2a Regulatory or management effectiveness

The legal basis for an EIA for new farms is discussed in Factor 2.2, including the challenge that they are generally only applied to larger farms rather than the small-scale farms that make up the majority of the industry. Several requirements for triggering an EIA pertain directly to habitat, including “projects involving cutting of protected forest, tidal mangrove forests and special forest with total area over 20 ha, or cutting natural forests with total area over 200 ha” (Philips et al. 2009). Public participation and community notification in the EIA process is a requirement of Circular No 08/2006/TT-BTNMT, but it is unclear if the process is effective (Philips et al. 2009).

Mangrove forests are classified by the Vietnamese government as special-use, protection, or production forests (Hawkins et al. 2010) (McNally et al. 2011). Although several legal documents encourage mangrove preservation and prohibit the conversion of mangrove forests to aquaculture, mangroves are cut to provide timber, charcoal, and space for shrimp farming (Nair 2015). Reasons for continued cutting include low public awareness on the total economic value of mangroves, ineffective governmental mangrove protection with lack of activities that help local people benefit from mangrove conservation, and government policies that pursue high targets for shrimp farming production (Nam 2013). Increasingly, high shrimp production targets imposed by local government agencies are pressing farmers to expand or implement more intensive production systems (Nam 2013). As a consequence, adverse impacts on mangrove ecosystems have increased.

Regarding the historic, current, and future controls on the size of the industry and its cumulative impacts, there is little to suggest effective planning. According to a review by Van et al. (2015), National Decree 773-TTg in 1994 stipulated that open coastal areas and waterbodies could be used for aquaculture with 5-year tax breaks for those clearing the mangrove forests; this policy resulted in shrimp farmers clearing even more mangrove forests for aquaculture activities. Additionally, the control of land-use decisions is made at the provincial level, where the economic situation favors shrimp farming (Van et al. 2015). But going forward, this may improve. Eight provincial level governments that control land-use planning, including the main producing region of Ca Mau, are working with The World Bank on the Coastal Resources for

Sustainable Development (CRSD) Project. The project includes a component on integrated spatial planning of all coastal areas and across sectors. (Nair 2015). Additionally, Circular No. 4512010rrT-BNNPTNT of July 22, 2010 requires that all intensive shrimp farms built after August 2010 must be sited in a designated aquaculture zone; however, this does not apply to any farm built before that date.

In addition to controls of further losses, there are regulatory tools for encouraging mangrove restoration. The Central Vietnamese government programs for mangrove management activities, such as reforestation and conservation actions, date back to 1978 (Binh et al. 2005). More recently, in 2010, Decree No. 99 mandated the implementation of the Payment for Forest Environmental Services (PFES) nationwide (Nair 2015), which resulted in some of the fees collected being used to improve the overall health of watersheds by forest restoration (Thu Thuy 2013 cited in Nair 2015). Hong (2003) estimated that, of the 155,290 ha of mangrove at the time, 96,876 ha were planted in a number of reforestation programs, including a 53,000-ha project in Ca Mau Province (IUCN 2012 cited in Van et al. 2015). But these restoration projects were not fully based on ecological principles that would ensure success (i.e., planting a single species) (IUCN 2012 cited in Van et al. 2015).

The regulatory effectiveness on shrimp farming in Vietnam is considered moderate for farm siting due to the requirement of an EIA, but is limited to large farms only. Given that the majority of the industry is below these size limits, the regulatory controls only partly address the industry's total size. Future controls, including marine spatial planning, may moderately control the future loss of ecosystem services, but it is evident that further mangrove conversion for new farms is not prohibited. Control measures for restoring habitat exist, but the incentive to increase production rather than mangrove forest coverage suggests only moderate controls. Overall, these result in a score of 1.75 out of 5 for Factor 3.2a for all production systems.

<u>Factor 3.2b Siting regulatory or management enforcement</u>
MARD is responsible for monitoring compliance with national standards, but no specific information was available to determine whether it currently has the resources to regulate the scale of the industry. Philips et al. (2009) found that provincial environmental authorities lacked sufficient facilities, laboratories, and suitable staff to effectively monitor aquaculture, suggesting that current systems are unlikely to be appropriate to the scale of the industry.

The engagement with the World Bank and the regulations introduced in 2010 suggest partial control based on zoning, which could improve scores in the future. Integrated shrimp-mangrove systems are potentially the best example of permitting, according to the cumulative impacts of the industry on habitat. Vo et al. (2013) recently commented on this mangrove-shrimp system, stating that the mangrove forests of Ca Mau peninsula are divided into:

- A Full Protection Zone (FPZ): in which all land must be forested and conserved, and on which no human settlements are allowed except for fishing communities at river mouths
- A Buffer Zone (BZ): where 60% of the area must be covered by mangroves, while the remaining 40% can be utilized for agriculture or aquaculture

But Figure 10 shows clearly that compliance with the BZ 60% mangrove cover is not adhered to by farmers; mangrove density has been reduced and “illegal” enlargement of aquaculture area has occurred (Vo et al. 2013).

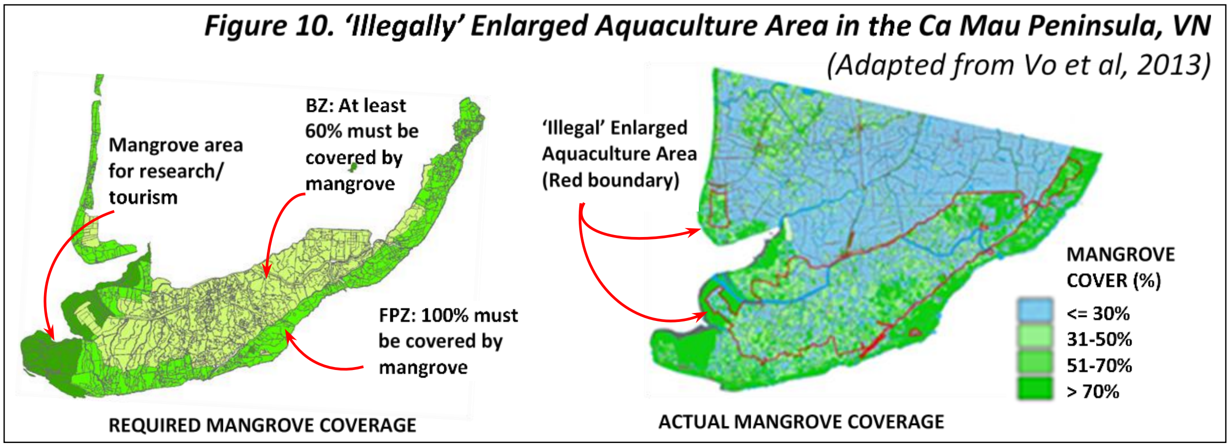


Figure 10. Legal compliance with mangrove coverage requirements in Vietnam (adapted from Vo et al. 2013).

Although the benefits of integrated shrimp-mangrove aquaculture are recognized, implementation has been poor due to ineffective regulation and a lack of economic incentives (Ha et al. 2012a). High income from shrimp farming encourages farmers to increase the area of aquaculture by illegally cutting mangroves (Binh et al. 1997) (Minh et al. 2001) (Tong et al. 2004) (Lam-Dao et al. 2011) (Vo et al. 2013). Poor management, such as maintaining the water level too high in the ponds, can also lead to mangrove death. According to Nair (2015), the Vietnamese government does not yet have the capacity for punitive enforcement for mandatory standards, and has to rely on encouraged self-regulation. The available evidence suggests that habitat control measures are not being achieved.

Scoring for Factor 3.2b, siting regulatory or management enforcement, is summarized below. Enforcement organizations are identifiable but questions remain about whether they are appropriate for the scale of industry, resulting in a moderate ranking. The permitting process will potentially be zonally based in the future, but this has not historically been the case, resulting in a score of 0.25. Regulations addressing mangrove cover in integrated shrimp-mangrove systems show moderate consideration of cumulative impacts on habitat. The EIA process is public but only applied to larger farms, and questions remain about its effectiveness, resulting in a moderate score. Finally, there is little evidence that control measures are being achieved but some mangrove coverage (≈30%) is being retained, resulting in a partial score of 0.25. This gives a combined score of 2 out of 5 for Factor 3.2b.

The scores from Factor 3.2a and 3.2b are combined to give a score of 1.4 out of 10 for Factor 3.2 Habitat Management for all production systems.

Conclusions and Final Score

Overall, the combination of both historical and very recent critical habitat losses with insufficient enforcement of regulation gives a final Criterion 3 – Habitat numerical score of 1.13 out of 10 for all production systems. It should be noted that suitable verification of legal compliance would be sufficient to obtain a higher habitat score for all production systems, particularly the integrated shrimp-mangrove system.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- *Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments*
- *Principle: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use*

Criterion 4 Summary

All species and production systems

Chemical Use parameters	Score	
C4 Chemical Use Score	**0.00**	
C4 Chemical Use Final Score	**0.00**	**RED**
Critical?	NO	

Brief Summary

Asian shrimp aquaculture is known to use a variety of chemicals over the course of the production cycle, though the environmental impacts of these are not always known. Of significant concern is the use of antimicrobials, which proliferate resistant pathogens that affect shrimp health and potentially human health. Detailed data on chemical or antibiotic usage in Vietnam are not available. Reports range from minimal usage of chemicals and antibiotics to reports that WHO-listed, critically important and highly important antimicrobials are being used on Vietnamese shrimp farms. There is clear evidence from U.S. FDA and EU import rejections and in the literature that illegal antibiotic use is occurring. A fundamental issue could be that uninformed farmers can access antibiotics without a prescription. The evidence available is sufficient to warrant a score of 0 out of 10 for Criterion 4 – Chemicals for more intensive production (i.e., whiteleg shrimp). There is potentially less clarity with the extensive systems used for giant tiger prawn, but there is no way to differentiate production systems or species linked to the majority of import rejections (except for two rejections by the EU that specifically refer to giant tiger prawn). From the precautionary perspective, all the production systems must be considered linked to illegal chemical use, so a score of 0 out of 10 is given for Criterion 4 – Chemicals for both giant tiger prawn systems.

Justification of Ranking

As the aquaculture industry continues to grow on a global scale, concerns regarding the use (and misuse) of drugs and chemicals in aquaculture have increased substantially (FDA 2007b) (Lumpkin 2007). Global expansion of commercial aquaculture has resulted in the routine use of veterinary medicines (and chemicals) to improve the health of stocks and to maximize production (Bondad-Reantaso et al. 2012).

In general, aquaculture throughout Asia is known to use a variety of chemicals to address issues such as water quality or disease, and the environmental impact of these chemicals is often unknown (Rico et al. 2012) (Gräslund and Bengtsson 2001). According to a review of the environmental risks of chemical and biological products in Asian aquaculture (but not Vietnam specifically) by Rico et al. (2012), "chemicals, disinfectants, pesticides and antibiotics have been shown to be the most environmentally hazardous compounds owing to their high toxicity to non-target organisms and/or potential for bioaccumulation over tropic chains, and can potentially affect the biodiversity and functioning of adjacent aquatic ecosystems." More specific details from the Rico et al. (2012) review are shown in Table 6.

Table 6. Types of chemicals used in Asian aquaculture and their potential environmental impacts (from Rico et al. (2012) and sources within).

Type of Chemical	Relevant example chemicals	Potential environmental impacts
Water and sediment treatment compounds	Lime to control pH	Short term changes in local water quality (e.g., pH).
Fertilizers	Urea to promote algal growth as an additional food source.	Increased nutrient discharges in effluents; eutrophication.
Pesticides	Saponin (teaseed cake), rotenone used to kill fish prior to pond stocking.	Can also kill nontarget organisms. Can significantly decrease zooplankton population.
Disinfectants	Chlorine, sodium hypochlorite, benzaklonium chloride used in hatcheries and ponds to kill fungal and parasitic pathogens before stocking.	Range from moderate to highly toxic impacts on plankton and larger invertebrates but often easily diluted and degraded in the environment,
Antibiotics	Oxytetracycline	Toxic to microorganisms and phytoplankton. Potential long-term exposure to invertebrates can disrupt reproduction. Disruption of the basis of the food web, local bacterial communities, and ecosystem functions such as nitrification. Bioaccumulation in top predators.

One of the most concerning issues is the use of antimicrobials that may also pose a risk to human health (Gräslund and Bengtsson 2001) because significant use of these drugs can further the development of antimicrobial-resistant pathogens, including those capable of cross-species and zoonotic transmission (Holmström et al. 2003).

The current situation regarding chemical and antibiotic use in Vietnam is unclear. For example, a study by Thuy et al. (2011) surveyed 71 farmers, including 2 hatcheries (termed "larvae farming" in the study), in Can Gio and Can Duoc districts, and found significant use of antibiotics in the hatcheries but also some use on the farms (see Table 7 below; noting that the date of the survey was unclear in the report). The authors went on to state that "several antibiotics commonly used in Vietnamese shrimp culture have been detected in wastewater and sediment of the ponds, as well as in surrounding coastal wetlands, resulting in the existence of antibiotic-resistant bacteria. However, their transport and fate could not be clearly defined" (Thuy et al. 2011).

Table 7. Results of a survey of 71 shrimp farmers in Can Gio and Can Duoc districts (copied from Thuy et al. 2011).

No.	Commercial name	Composition	Percentage of farmers (%)	Usage for
1	Ciprofloxacin 500 mg	Ciprofloxacin	100	Larvae
2	Cotrim	Sulfamethoxazole	8.7	Postlarvae to adult shrimp
3	Cotrim-La	Sulfamethoxazole, Trimethoprim	n.a	Postlarvae to adult shrimp
4	Daitrim	Sulfamethoxazole 10%, Trimethoprim 2%	n.a	Postlarvae to adult shrimp
5	Griseofulvin 500 mg	Griseofulvin	100	Larvae
6	N300	Norfloxacin, hydrochloride 30%	n.a	Postlarvae to adult shrimp
7	Osamet	Sulfadimethoxine 25%, Ormetoprim 5%	11.2	Postlarvae to adult shrimp
8	Prawnox	Oxolinic acid 25%	n.a	Postlarvae to adult shrimp
9	Rifampicin 300 mg	Rifampicin	100	Larvae
10	Romet 30	Sulfadimethoxin 25%	n.a.	Postlarvae to adult shrimp
11	Silva 54	Sulfadiazine, Trimethoprim	n.a	Postlarvae to adult shrimp
12	Sulfa-prim	Sulfadiazine, Trimethoprim	21.74	Postlarvae to adult shrimp
13	TA-2 oxytetracyline	Oxytetracyline	100	Larvae
14	TMT	Sulfadiazine, Trimethoprim	15.9	Postlarvae to adult shrimp

Note: data collected from 71 farmers (including two larvae farming) in wetland of Can Gio and Can Duoc districts
n.a the data is not available

In contrast, a study by Rico et al. (2013) surveyed 34 intensive and semi-intensive shrimp farms in Soc Tran and Bac Lieu provinces in the Mekong River Delta between 2011 and 2012 regarding their use of chemicals and drugs. Only one farm reported using an antibiotic, specifically oxytetracycline, while five farms reported using disinfectants, primarily chlorine but also iodine, benzalkonium chloride, potassium monopersulfate, and formaldehyde. Over 90% of the surveyed farms reported using probiotics (Rico et al. 2013). On average, the amount of chemical input per ton of harvested Vietnamese shrimp was 16 kg, of which approximately 4.8 kg per ton of production were predominantly disinfectants and applied for disease prevention (Rico et al. 2013).

It would be expected that the small-scale extensive nature of the giant tiger prawn production systems would mean that no chemicals or antibiotics would be used. Bosma et al. (2014) claimed that semi-extensive farmers hardly use any chemical inputs, while Ha et al. (2014) claimed that no lime or other chemicals were used; only *Derris* (a pest control plant) was used to kill predator organisms in integrated shrimp-mangrove systems. But a report by Hambrey Consulting (2009) stated that "the use of antibiotics in the more extensive systems being relatively rare but not unheard of" and characterized the likelihood of increasing antibiotic resistance, the severity of its impact, and the degree of uncertainty of these risks for small-scale systems as "moderate."

The easy access to antibiotics is potentially a real concern in Vietnam; according to a review by Uchida et al. (2016), "it has been reported that, in Vietnam, farmers can purchase antibiotics easily and without a prescription, and many farmers have insufficient information about appropriate use of the drugs."

Evidence of current abuses of antibiotics can be found for Vietnam; for example, in the first half of 2014, Japan and the EU repeatedly warned Vietnam about residues that exceeded permitted limits for oxytetracycline, a type of antibiotic used to control disease (Nair 2015). Between 2014 and July 2016, the U.S. FDA (2016) rejected 101 shipments of farmed shrimp from Vietnam due to the presence of illegal veterinary drug residues. Unfortunately, the U.S. FDA does not differentiate shrimp by species, production system, or the type of veterinary drug found in its record system, so there is no way to determine if all the rejections were for intensive systems. But 34 shipments originated from processing facilities in Ca Mau, where integrated shrimp-mangrove systems are the dominant production system, which suggests at least a possible link between some of these systems and illegal veterinary drug abuse. Between the start of 2014 and October 2016, the EU rejected 38 containers of shrimp from Vietnam with illegal residues of antibiotics; 27 specifically for whiteleg shrimp (primarily oxytetracycline), 2 specifically for giant tiger prawn (oxytetracycline and sulfadiazine), and a further 9 containers where the species of shrimp were undifferentiated (RASFF Portal 2016).

Furthermore, the Uchida et al. (2016) review states that "Vietnamese authorities began a residual monitoring program for certain harmful substances in 2009. Fishery aquaculture products were collected at intensive aquaculture sites in 37 provinces/cities. Antibiotics such as tetracyclines, sulfonamides, quinolones, florfenicol, trimethoprim, and neomycin were analyzed. Samples violated the Vietnam MRLs for antibiotics at a rate of 1.0% in 2014, and seven antibiotics (sulfadimethoxine, sulfadiazine, enrofloxacin, ciprofloxacin, oxytetracycline, doxycycline, and trimethoprim) were detected [noting the study looked at both fish and shrimp aquaculture]." The authors also speculated that the use of illegal antibiotics might be lower in export production than domestic production due to the degree of testing and market disincentives for products with illegal residues (Uchida et al. 2016).

Uchida et al. (2016) tested shrimp from markets in both urban and rural areas of Vietnam for both antibiotic residues. In the study, the authors claimed to be focused on "intensive" production, but they did not differentiate between shrimp species or present evidence how they could be certain that extensive products were not included in the study. Out of the 160 shrimp tested in the urban areas, 14 had residues of antibiotics (4 with ciprofloxacin, 12 enrofloxacin, 1 oxolinic acid, and 2 with sulfamethazine [the discrepancy in the total suggesting that some shrimp may have had multiple residues]) while in the rural areas only 2 shrimp out of 87 had detectable residues (sulfmathoxazole and trimethoprim) (Uchida et al. 2016). The report concluded that "inappropriate treatments at farms and/or distribution systems persist" (Uchida et al. 2016).

Of the antibiotics reportedly used in Vietnam, three are listed as critically important and two listed as highly important for human medicine by the World Health Organization (WHO) (2017); further details are given in Table 8.

Table 8. Antibiotics reportedly used in Vietnamese shrimp farming and their World Health Organization status in the Critically Important Antimicrobials for Human Medicine 5th Revision 2017.

Antibiotic	World Health Organization (2017) 3Status
Ciprofloxacin, Enrofloxacin, Oxolinic acid	**Critically Important** Criterion 1: Limited therapy for *Campylobacter* spp., invasive disease due to *Salmonella* spp. and MDR (multiple drug resistant) *Shigella* spp. infections. Criterion 2: May result from transmission of *Campylobacter* spp. and Enterobacteriaceae including *E. coli* and *Salmonella* spp. from nonhuman sources.
Oxytetracycline	**Highly Important** Criterion 1: Limited therapy for infections due to *Brucella*, *Chlamydia* spp., and *Rickettsia* spp.
Sulfamethazine, Sulfmathoxazole, Trimethoprim	**Highly Important** Criterion 2: May result from transmission of Enterobacteriaceae including *E. coli* from nonhuman sources.
Griseofulvin	No record
Oremetoprim	No record

Conclusions and Final Score

In summary, there is a lack of relevant and up-to-date data on chemical use in all types of shrimp farming in Vietnam, particularly regarding antibiotics. Evidence suggests that chemicals are used to kill vectors in some systems prior to stocking. Although there are conflicting reports on the type and use of antibiotics, there are accounts of three critically important and two highly important antimicrobials being used, possible evidence of antibiotic resistance, and substantial evidence that illegal drug usage is a current issue in Vietnamese shrimp farming. These issues may be exacerbated by the lack of an effective, prescription-based regulatory system and lack of education by farmers. This evidence is sufficient to warrant a score of 0 out of 10 for Criterion 4 – Chemicals for more intensive production (i.e., whiteleg shrimp). There is potentially less clarity with the extensive systems used for giant tiger prawn, but there is no way to differentiate production systems or species linked to the majority of import rejections (though two from the EU specifically refer to giant tiger prawn), so from the precautionary perspective, all the production systems, including the extensive and integrated shrimp-mangrove giant tiger prawn systems, must be considered linked to illegal chemical use and a score of 0 out of 10 for Criterion 4 – Chemicals.

Criterion 5: Feed

Impact, unit of sustainability and principle

- *Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.*
- *Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.*
- *Principle: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Criterion 5 Summary

Giant tiger prawn – Integrated shrimp-mangrove pond systems and extensive systems

C5 Feed Final Score		**10.00**	**GREEN**
Critical?	NO		

Whiteleg shrimp – Intensive pond systems

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	1.11	7.22	
F5.1b Source fishery sustainability score		–6.00	
F5.1: Wild Fish Use		6.56	
F5.2a Protein IN	40.42		
F5.2b Protein OUT	14.86		
F5.2: Net Protein Gain or Loss (%)	–63.2	3	
F5.3: Feed Footprint (hectares)	7.52	7	
C5 Feed Final Score		**5.78**	**YELLOW**
Critical?	NO		

Brief Summary

The two main production systems for giant tiger prawn operate without the use of supplemental feed, resulting in a score of 10 out of 10 for Criterion 5 – Feed.

Whiteleg shrimp is farmed utilizing compound feed that contains relatively high amounts of fishmeal (20%) but only small amounts of fish oil (2%). The average FCR is relatively low at 1.25, resulting in a Fish In:Fish Out (FIFO) value of 1.11. Current data on Vietnamese sources of fishmeal and fish oil that are used as ingredients in shrimp feeds were unavailable; this unknown status resulted in a Factor 5.1b score of –6 out of –10. The net protein loss from feed was 63.2%, with an estimated feed footprint of 7.15 ha of ocean area and 0.37 ha of land area per ton of whiteleg shrimp production. Overall, the final score for whiteleg shrimp is 5.78 out of 10 on Criterion 5 – Feed.

Justification of Ranking

<u>Giant tiger prawn</u>
Both giant tiger prawn systems are extensive and do not use external feed (Hanley 2007) (Ha et al. 2012) (Jonell and Henriksson 2014) (Jory and Cabrera 2012) (Tacon et al. 2004) (White et al. 2013). This results in a score of 10 of 10 for Criterion 5 – Feed.

<u>Whiteleg shrimp</u>
Whiteleg shrimp are farmed intensively using pelleted industrial feed (Anh et al. 2010); Factors 5.1, 5.2, and 5.3 below are only related to whiteleg shrimp farming.

Factor 5.1. Wild Fish Use
Current and detailed data were not found on whiteleg shrimp feed in Vietnam, including feed conversion ratios (FCRs), protein content, and sources of fishmeal and fish oil. One company, AG Food Commodities (2016), offered several types of fishmeal from Vietnamese sources including sea fishmeal from “mixed ocean sources” and farmed *Pangasius* byproducts. But a 2004 report by Edwards et al. found, at the time, that Vietnam imported 90% of the fishmeal and 100% of the fish oil used in crustacean feeds because of the low quality of domestic sources. At the time, the source of the imported fishmeal was “mainly Peru” and all of the fish oil came from South Korea (Edwards 2004). The Edwards et al. (2004) report also claimed that 60% of the protein in shrimp feed was supplied by the fishmeal (suggesting that 40% would be from crop sources) and that fishmeal inclusion rates varied from 20% to 50%, noting that this was for giant tiger prawn feed rather than whiteleg shrimp. A slightly more recent but still dated report by Tacon and Metian (2008) reported that the average FCR in Vietnamese shrimp farming was 1.6 (ranging between 1.2 and 1.8), average fishmeal inclusion in feed was 20% (ranging from 10% to 30%) and average fish oil 2% (ranging 1% to 3%).

As noted in Criterion 2 – Effluent, reported feed conversion ratios (FCR) for intensively farmed whiteleg shrimp vary from 1.1 to 1.4 (VDoA 2008) (Hung and Quy 2013) (Long et al. 2013) (pers. comm., Micciche 2013) (Quoc 2016). Based on these data sources, an average economic FCR (eFCR) value of 1.25 is used in this assessment and considered to be currently representative of the intensive whiteleg shrimp farming industry in Vietnam. Based on the information above, this report also assumes a 20% fishmeal and 2% fish oil inclusion rate in the feed. None of the fishmeal or oil was considered to be from by-product sources. The source fisheries data are not considered recent or clear enough to be included in the assessment, so they are classified as coming from unknown sources. This means that a standard yield of 22.5% fishmeal and 5% fish oil was used.

Based on the data cited above, whiteleg shrimp is estimated to have a fish in:fish out (FIFO) ratio of 1.11, which means it takes 1.11 kg of wild fish to produce 1 kg of farmed shrimp. This

FIFO value results in a score of 7.22 out of 10 for whiteleg shrimp for Factor 5.1a – FIFO. The unknown status of the source of the wild fish used in feed receives a score of –6 out of –10 for Factor 5.1b Sustainability of the Source of Wild Fish (SSWF) (scores range between 0 and –10), and results in a deduction from the Factor 5.1a score of –0.67.

This resulted in a score of 6.56 out of 10 for Factor 5.1 Wild Fish Use.

Factor 5.2. Net Protein Gain or Loss

In Vietnam, feeds contain protein levels ranging from 36% to 44% (Hung and Quy 2013), so an average of 40% is used in this assessment. With a total fishmeal content of 20% and an assumed fishmeal protein content of 66.5%, it is estimated that marine ingredients (i.e., fishmeal) contribute 33% of the total feed protein. Because no other protein-contributing ingredients are known, it is assumed that the remaining 67% of feed protein is provided by crop sources. With no robust information that any proteins are from by-products or other nonedible sources, all protein is considered to be suitable for human consumption.

The protein content for whiteleg shrimp is 17.8% (Boyd 2007). According to Briggs et al. (2004), the processing conversion rates for whiteleg shrimp are 66%–68% (67% is used for this report). It is unknown if any of the nonedible parts of a harvested shrimp (e.g., head, shells) are used for further protein production, so a default value of 50% was used. Based on the data cited above, the whiteleg shrimp growout cycle protein budget resulted in a 63.2% protein loss.

These values achieve a score of 3 out of 10 on Factor 5.2 for whiteleg shrimp.

Factor 5.3. Feed Footprint

The feed footprint factor takes into account all the feed ingredient inputs on the basis of the area of primary productivity appropriated to produce them. The feeds for whiteleg shrimp are considered to contain around 22% marine ingredients (fishmeal and fish oil) and 78% from a range of crop sources (e.g., soybean, wheat). Combined with the eFCR of 1.25, these factors result in an estimated requirement for 7.15 ha of ocean area and 0.37 ha of land area per ton of whiteleg shrimp production. These areas equate to score of 7 out of 10 for whiteleg shrimp for Factor 5.3 - Feed Footprint.

Conclusions and Final Score

The two main production systems for giant tiger prawn operate without the use of supplemental feed, resulting in a score of 10 out of 10 for Criterion 5 – Feed. Whiteleg shrimp requires relatively high amounts of protein in its diet and results in a significant total loss in protein; but the species is relatively feed-efficient, so the overall impact is moderate. This score could change substantially if further data on the sources of marine feed ingredients became available. The scores for Factors 5.1, 5.2, and 5.3 combine to give a final numerical score for Criterion 5 – Feed of 5.78 out of 10 for whiteleg shrimp.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, predation, habitat damage , spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations*
- *Sustainability unit: affected ecosystems and/or associated wild populations.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Criterion 6 Summary

Giant tiger prawn – Integrated shrimp-mangrove pond systems and extensive systems

Escape parameters	Value	Score	
F6.1 Escape Risk		5.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		8	
C6 Escape Final Score		**6.00**	**YELLOW**
Critical?	NO		

Whiteleg shrimp – Intensive pond systems

Escape parameters	Value	Score	
F6.1 Escape Risk		6.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		4.5	
C6 Escape Final Score		**4.00**	**YELLOW**
Critical?	NO		

Brief Summary

Both giant tiger prawn systems frequently exchange water and present a high risk of escapes; however, the low stocking densities used result in score of 5 out 10 for Factor 6.1a. Both systems also supplement ponds with wild seed that is passively collected when the ponds are filled with hatchery-raised seed from wild-caught broodstock. These seed represent a minor risk of impact to the local wild stocks because they are one generation and hatchery-raised, and result in a Factor 6.1b score of 8 out of 10. Ultimately, the final numerical score is 6 out of 10 for Criterion 6 – Escapes for both giant tiger prawn systems.

Whiteleg shrimp farms limit water exchange and maintain infrastructure that reduces the risk of escape. The score for Factor 6.1a is 6 out of 10. Whiteleg shrimp is nonnative to Vietnam and raised from imported broodstock, potentially having a larger escapement impact if it were to become ecologically established. Although establishment has not been shown in other countries where the species has been introduced, it remains poorly studied. The score for Factor 6.1b is 4.5 out of 10. Overall, whiteleg shrimp is considered to have a moderate risk of escapement and a moderate risk for impact, resulting in a score of 4 out of 10 for Criterion 6 – Escapes.

Justification of Ranking

Factor 6.1a. Escape risk
The three different production systems assessed in this report have slight differences that are relevant to Criterion 6 –Escapes, but all systems are not considered to have significant recapture or mortality of escaped shrimp.

Giant tiger prawn
Extensive giant tiger prawn systems rely primarily on hatchery-raised seed (World Bank 2010) (Hung and Quy 2013) (Bosma et al. 2014) (Ha et al. 2014) (Joffre 2015) (Quoc 2016) and also on frequent water exchanges with natural waterbodies to improve water quality (World Bank et al. 2006) (Joffre et al. 2015). Integrated shrimp-mangrove systems primarily use wild seed that is passively collected during bimonthly water exchanges, but also supplement with hatchery-raised seed in order to achieve desired (though low) stocking densities (Tho et al. 2011) (Joffre et al. 2015). Although slightly different, both systems are considered systems of high exchange (>10% per day) and low technology that are unlikely to be applying best management practices for preventing escapes. This is considered moderate-high risk, typically resulting in a score of 2 out of 10, but the very low stocking densities (<2 PL/m^2) must be considered, raising the score to 5 out of 10 for both giant tiger prawn systems for Factor 6.1a – Escape risk.

Whiteleg shrimp
Whiteleg shrimp was illegally introduced to Vietnam in 2000 but can now be legally farmed (FAO 2013) (VASEP 2014) (Nair 2015). Intensive whiteleg shrimp farms use hatchery-raised seed from imported broodstock, and they limit water exchange (0%–3% per day) (Joffre and Bosma 2009). Circular No. 4512010rrT-BNNPTNT of July 22, 2010 (relevant to intensive whiteleg shrimp and giant tiger prawn production only) also includes several requirements for farm infrastructure, including that “a rearing pond must cover at least 3,000 m^2 of water surface; the minimum depth from pond bed to water surface must be 2 m and the pond banks must be solid and leak-free” and also that “ponds must be built with solid separate water supply and water drainage sluice gates against leaking.” No data were available to quantify the effectiveness of this regulation, nor was it apparent that escape monitoring or reporting data exist. This information results in a score of 6 out of 10 for Factor 6.1a – Escape risk.

Factor 6.1b. Invasiveness
Giant tiger prawn
Both extensive systems for giant tiger prawn use wild PLs collected when the ponds are filled with water along with additional supplemental seed from hatcheries. Though the degree of supplementation differs between the two, it is unlikely to be different enough to warrant

separate scoring on Factor 6.1b, so the more risky source (supplemental hatchery-raised seed) is used for scoring, using the precautionary approach. Data on the sources of giant tiger prawn broodstock (including collection practices and the fishery) were either extremely dated or could not be found. According to a 2005 Better Management Practices (BMP) manual for giant tiger prawn hatcheries in Vietnam published by NACA, the country depended completely on the capture of wild broodstock, which were then spawned at a hatchery. References exist to studies investigating domesticated broodstock (e.g., Hoa 2009), but no evidence was found to suggest that these sources are currently used substantially in Vietnam. Indications of a potential shift in that strategy can be seen, because Vietnam imported a small number (6,000) of domesticated, specific pathogen free (SPF) giant tiger prawn broodstock from Hawaii in 2015 (pers. comm., Yamasaki 2016). Because the majority of growout stock are one generation and hatchery-raised, the current situation results in a score of 4 out of 5 for Part A. Escaped giant tiger prawns would likely be able to compete to some extent with wild stocks for food, habitat, and mates, but are unlikely to place additional predation pressure on wild stocks, modify habitats to the detriment of other species (since any impact would be the same as the wild stocks), or have additional impacts on habitat or other species. This results in a score of 4 out of 5 on Part C of Factor 6.1.b.

The final score for Factor 6.1b for giant tiger prawn farmed in both extensive and integrated-shrimp mangrove systems is 8 out of 10.

Factors 6.1a and 6.1b combine to give a final numerical score of 6 out of 10 for Criterion 6 – Escapes for both giant tiger prawn systems.

<u>Whiteleg shrimp</u>
Whiteleg shrimp is nonnative to Vietnam and it is unknown if it is established yet in the wild in Vietnam (FAO 2016b). No research to evaluate the ecological impact of escaped whiteleg shrimp in Vietnam was apparent. In Thailand, where whiteleg shrimp has been farmed since 1998, some research has indicated that no significant impacts were evident to fishers or the Thai Department of Fisheries (Briggs et al. 2004), but later studies showed that whiteleg shrimp, including gravid females, was present in the wild in Thailand (Senanan et al. [2010], referring to 2005 and 2006 sampling data). But its presence was possibly due to repeated escapes, so any conclusions regarding its establishment were not possible. This suggests that the potential impacts of escaped whiteleg shrimp on native shrimp stocks in general may be limited. But similar shrimp species have potentially become established in other countries, so a score of 0.5 out of 2.5 is given for Part B of Factor 6.1b. For Part C of Factor 6.1b, there is no evidence yet that whiteleg shrimp has established or is causing ecological problems after many huge escape events in SE Asia; therefore, the score is 4 out of 5.

The final score for whiteleg shrimp for Factor 6.1b is 4.5 out of 10.

Factors 6.1a and 6.1b combine to give a final numerical score of 4 out of 10 for Criterion 6 – Escapes for whiteleg shrimp.

Conclusions and Final Score

All three systems present a moderate risk of impacts resulting from escapes. Both giant tiger prawn systems frequently exchange water and present a high risk of escapes, but low stocking densities and limited risks of impacts associated with passively collected seed or hatchery-raised seed from wild-caught broodstock result in a final numerical score to 6 out of 10 for Criterion 6 – Escapes. By comparison, the non-native whiteleg shrimp raised from imported broodstock are potentially riskier regarding escapement impact, but low-exchange ponds and the lack of historical establishment in other countries result in overall score of 4 out of 10 for Criterion 6 – Escapes.

Criterion 7. Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

- *Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body*
- *Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Criterion 7 Summary

All species and production systems

Pathogen and parasite parameters	Score	
C7 Biosecurity	5.00	
C7 Disease; pathogen and parasite Final Score	**5.00**	**YELLOW**
Critical?	**NO**	

Brief Summary

Diseases can be extremely damaging to shrimp farms but are less pronounced on extensive farms than intensive farms. As a result, intensive farming may present a higher risk of disease outbreaks. In Vietnam, intensive farms are required by law to apply much stronger biosecurity measures than extensive farms. Conversely, poor management of disease-contaminated water in extensive farming has the greatest potential to spread diseases to other farms and/or wild populations. The tradeoffs between the two production strategies mean that all production systems can be assessed together in terms of their risk to wild populations. Though many shrimp diseases can be transferred to wild populations of shrimp and other species, the actual impact of on-farm disease on wild populations remains unclear. The various considerations mean that there is a moderate concern for disease-related impact in Vietnam, resulting in a final score of 5 out of 10 for Criterion 7 – Disease.

Justification of Ranking

Transmittable diseases that may present serious socioeconomic and/or public health threats are tracked globally by the World Organization for Animal Health (OIE) (OIE 2016a). OIE-listed diseases affecting farmed marine shrimp include white spot syndrome virus (WSSV), yellow head virus (YHV), Taura syndrome virus (TSV), infectious myonecrosis virus (IMNV), necrotizing hepatopancreatitis (NHP), and infectious hypodermal and haematopoietic necrosis virus (IHHNV) (OIE 2016a). Of these, WSSV, TSV, and YHV are the most problematic globally (Walker and Mohan 2009). YHV is thought to have a limited impact on whiteleg shrimp compared to giant tiger prawn, with the opposite assumed of TSV, IMNV, and IHHNV (Walker and Mohan 2009). Of additional concern to shrimp farming is Early Mortality Syndrome (EMS), the common name for acute hepatopancreatic necrosis syndrome (AHPNS), which is also OIE-listed (Nikolik and Kumar 2013) (OIE 2016a).

According to the OIE (2016b), data supplied by Vietnam on OIE-listed diseases in 2015 (which were not shrimp species-specific) showed that WSSV was present in the country and that the last reported outbreaks of reportable diseases included NHP on farms in 2012, YHV on farms in 2014, and YHV in wild populations in 2007. Vietnam had never reported outbreaks of IHHNV, INMV, or TSV, which were the subjects of general surveillance (OIE 2016b). EMS was first detected in China in 2009 and subsequently spread to Vietnam (Nikolik and Kumar 2013). There is concern that EMS has become endemic in the country (Lightner et al. 2012) (Akazawa and Eguchi 2013 cited in Joffre et al. 2015).

According to Nair (2015), there is a correlation between higher stocking densities and shrimp disease, which is true of both intensive and extensive systems. Diseases are generally less virulent in extensive systems than intensive systems, even when the latter apply strong biosecurity measures (Hoa et al. 2011). But it is clear that diseases can enter shrimp farms during water exchanges, which extensive farms do frequently and often without any biosecurity measures such as pre-treatment (Hambrey Consulting 2009). According to Nair (2015), extensive farmers respond to disease by discharging wastewater, and that this poor management of water contaminated by disease posed a risk to the environment. The supplementary use of hatchery-raised seed may also be an issue for extensive giant tiger prawns, because the use of hermit crabs as feed to broodstock has been shown to introduce WSSV to previously WSSV-free hatchery stocks (Chang et al., 2012). The above evidence suggests that the expression of disease may be low on extensive farms but they may still play a significant role in spreading disease to other farms and potentially wild stocks.

Intensive whiteleg shrimp farms in Vietnam apply some biosecurity measures, including limited water exchange (0%–3% daily). Circular No. 4512010rrT-BNNPTNT of July 22, 2010 requires that intensive farms:

- Treat influent to remove disease germs
- Improve pond beds
- Leave ponds fallow for one month after each production cycle
- Effluent must also be treated prior to discharge into the environment.
- Farms must develop shrimp health management plans.
- Dead and moribund shrimp must be removed and treated.
- Staff and equipment must be disinfected before being used in a different pond.
- All stocked PLs must come from approved sources and been certified to have passed a quarantine period.

The above practices are likely to reduce the introduction and spread of disease; however, there are no published data on compliance with these laws in Vietnam.

The impact of diseases transferred from shrimp farms to wild shrimp populations remains poorly understood (Walker and Mohan 2009). Several farmed shrimp diseases can cross species boundaries, including WSSV, TSV, and IMNV (Walker and Mohan 2009). For example, WSSV can be carried by a wide range of species and has been found in crabs and wild shrimp populations in regions where infected shrimp have been farmed (Walker and Mohan 2009). Lafferty et al. (2015) note: “It might appear that exports of WSSV into the wild would have impacts on wild crustaceans. After all, the virus enters the ocean through the farm effluent and shrimp escapes, and it affects many crustacean species. Interestingly, there are few reports of economic effects caused by viral release from aquaculture. One reason for this might be that the virus kills stressed shrimp in farm conditions, which do not apply to wild shrimp.”

One proposed example of a farmed shrimp disease affecting wild shrimp populations occurred in the 1990s, with an IHHNV outbreak in Mexico that resulted in significant losses in both farms and wild fisheries for the blue shrimp, *Penaeus stylirostris* (Lightner 2011).

Conclusions and Final Score

The available research suggests that disease outbreaks are not as common on extensive farms, but poor biosecurity measures and high water exchange are likely to contribute significantly to the spread of disease. Conversely, disease on intensive shrimp farms can be significant, but regulatory biosecurity measures are in place that could limit the spread of disease. In either case, transmission to wild populations is possible and shown with a report of YHV detected on wild stocks in Vietnam. Although further research is warranted, there is currently a lack of evidence of farm-origin diseases causing population-level impacts to wild shrimp, particularly in Vietnam. The tradeoff between the intensive and extensive systems in terms of disease outbreaks and biosecurity results in all production systems being considered a moderate risk to impacts on wild populations; thus, the final score is 5 out of 10 for Criterion 7 – Disease.

Criterion 8. Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for on-growing to harvest size in farms*
- *Sustainability unit: wild fish populations*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstocks, use minimal numbers, or source them from demonstrably sustainable fisheries.*

Criterion 8 Summary

Giant tiger prawn – Integrated shrimp-mangrove pond systems

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	50	
C8 Source of stock Final Score	**5.00**	**YELLOW**

Giant tiger prawn – Extensive pond systems

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	0	
C8 Source of stock Final Score	**0.00**	**RED**

Whiteleg shrimp – Intensive pond systems

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	100	
C8 Source of stock Final Score	**10.00**	**GREEN**

Brief Summary

Whiteleg shrimp depends entirely on hatchery-raised seed from domesticated broodstock and scores 10 out of 10 for Criterion 8 – Source of Stock. Both integrated and extensive giant tiger prawn systems use both passively collected post larvae (PLs) and hatchery-raised seed from wild-harvested broodstock. Data are exceedingly limited on the wild-broodstock stocks, so they cannot be considered sustainable. Based on an estimated 50% and 1% use of passively collected PLs on integrated shrimp-mangrove and extensive giant tiger prawn farms, respectively, the final score for Criterion 8 – Source of Stock is 0 out of 10 for extensive ponds and 5 out of 10 for integrated shrimp-mangrove systems.

Justification of Ranking

The three different production systems assessed in this report have slight differences that are relevant to Criterion 8 – Source of Stock. Extensive giant tiger prawn systems rely almost exclusively on hatchery-raised seed (World Bank 2010) (Hung and Quy 2013) (Bosma et al. 2014) (Ha et al. 2014) (Joffre 2015) (Quoc 2016), while integrated shrimp-mangrove systems for giant tiger prawn use both wild seed obtained from bimonthly water exchanges and supplementary stocking (Tho et al. 2011) (Joffre et al. 2015). For this criterion, based on the available literature, the ratios of wild stock to farmed stock are assumed to be approximately 1:99 for extensive farmers and 50:50 for integrated shrimp mangrove systems, because no consistency on specific ratios could be found.

<u>Giant tiger prawn</u>

Data on the sources of giant tiger prawn broodstock (including collection practices and the fishery) were either extremely dated or could not be found. This report assumes that, currently, all hatchery-raised giant tiger prawn seed is from wild-caught broodstock—while noting that Vietnam imported a small number (6,000) of domesticated, specific pathogen free (SPF) giant tiger prawn broodstock from Hawaii in 2015 (pers. comm., Yamasaki 2016). Although specific information was unavailable on the status of Vietnamese broodstock populations, Hoa (2009) described the situation in general as being unsustainable, based on both declining stocks and the vertical transmission of diseases. FAO data in 2009 that considered giant tiger prawn fisheries around Asia (not specifically Vietnam) suggested that landings had been increasing, but the species was subsequently considered "fully exploited" (but with a high degree of uncertainty) (FAO 2011). The NACA (2005) best management practices (BMPs) for hatcheries in Vietnam recommend that broodstock should be harvested using gill and trap nets and from "clean, deep water (30–60 m) as far as possible from the influence of the coast." This is unclear, but from a precautionary perspective, there is insufficient information to consider the wild broodstock fishery a sustainable resource. Additionally, broodstock can only be reused a number of times over a period of months (FAO 2006), suggesting that regular collection is necessary.

For the reasons above, extensive giant tiger prawn farming scores 0 out of 10 and integrated shrimp-mangroves system score 5 out of 10 for Criterion 8 – Source of Stock, based on the respective use of passively-collected PLs.

<u>Whiteleg shrimp</u>

Whiteleg shrimp farms only use hatchery-raised seed from domesticated broodstock (Joffre and Bosma 2009). According to estimates by Kawahigashi in 2009, Vietnam used a total of 70,000 broodstock, of which 20% were supplied directly from U.S. broodstock centers and 80% from Asian broodstock centers (which originally sourced U.S. broodstock). But this information conflicted with Hambrey Consulting's (2009) findings that 80% of seed imported into Vietnam came from China and was mainly untraceable and of poor quality. In 2015, Yamasaki (pers. comm. 2016) reported that Vietnam imported 101,380 specific pathogen free (SPF) broodstock from Hawaii, suggesting that the percentage from U.S. sources may have increased. Because either source is still domesticated, the final score for whiteleg shrimp is 10 out of 10 for Criterion 8 – Source of Stock.

Conclusions and Final Score

All three systems score differently because the domesticated whiteleg shrimp are entirely independent from wild stocks, and the giant tiger prawn systems supplement passively collected PLs with hatchery-raised seed from wild-caught broodstock; their uncertain population status prohibits their use from being considered sustainable. This resulted in final scores of 10 out of 10 for whiteleg shrimp, 5 out of 10 for giant tiger prawns raised in integrated shrimp-mangrove systems, and 0 out of 10 for extensively farmed giant tiger prawns for Criterion 8 – Source of Stock.

Criterion 9X: Wildlife and predator mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Criterion 9X Summary

Giant tiger prawn – Integrated shrimp-mangrove pond systems

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	0.00	GREEN
Critical?	NO	

Giant tiger prawn – Extensive pond systems
Whiteleg shrimp – Intensive pond systems

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	-4.00	YELLOW
Critical?	NO	

Brief Summary
Recent data on wildlife and predator mortalities associated with Vietnamese shrimp farming are lacking. General shrimp farming practices include treating ponds during the initial fill to kill resident organisms, but no specific measures used in Vietnam were found. Integrated shrimp-mangrove systems are an exception to this strategy, and do not generally remove predatory organisms. Passive and nonlethal measures, such as pond linings to deter predatory crabs and fireworks to deter diving birds, are also common in shrimp farming, but use of these practices could not be confirmed. Interactions between wildlife and shrimp ponds that result in mortality do likely occur on extensive giant tiger prawn farms and whiteleg shrimp farms, but are not thought to result in population-level impacts. Whiteleg shrimp and extensive giant tiger prawn systems each score a moderate deduction of –4 out of –10 for Criterion 9X – Wildlife and Predator Mortalities, whereas integrated shrimp-mangrove systems have no deduction (0 out of –10).

Justification of Ranking
Shrimp farming often requires the control of pests and predators, which can affect the cultured shrimp directly through predation and indirectly through competition for resources such as food (FAO 1986). Burrowing crabs can create an issue by damaging pond walls (FAO 1986). In general, predators on shrimp farms that can feed directly on shrimp can include amphibians, birds, crustaceans, finfish, mammals, and snakes (FAO 1986). General predator controls include

passive exclusionary systems, such as screens on inlets, netting, or pond linings, and active control systems, such as pesticides.

References to the specific predator species, the deterrents used to control them, or their impact on predator populations in the Vietnamese shrimp farming industry were not available in the literature. Circular No. 4512010rrT-BNNPTNT of July 22, 2010 requires that intensive farms treat influent water to remove harmful animals, but no further detail is provided. Most shrimp farms generally apply nonlethal, exclusionary techniques to scare birds away from the pond, such as fireworks or dogs during the production cycle (Gunalan 2015) (Balakrishnan 2011); however, Munasinghe et al. (2010) found that only 25% of Sri Lankan shrimp farms employed bird netting and there is no direct evidence of the employment of these strategies in Vietnam.

According to Bosma et al. (2014), integrated shrimp-mangrove systems are an exception to the typical strategy of predator exclusion. Predatory species such as crabs and fish are allowed to enter ponds along with target species during water exchanges. In addition, mangrove trees provide habitat to predatory birds and snakes (Burbridge and Koesobiono 1984, cited in Primavera 2000). But this conflicts with Ha et al. (2014), who claimed that *Derris* (a pest control plant) was used to kill predator organisms in integrated shrimp-mangrove systems.

No references to impacts on populations of fish or crustaceans as a result of these practices could be found. Though there are a number of IUCN Red-listed fish species found in Vietnam, none appears to be directly linked with predator control on shrimp farms (IUCN 2016).

Conclusion and Final Score

Some lethal control is applied on extensive giant tiger prawn and intensive whiteleg shrimp farms when the ponds are initially filled, but no clear evidence exists of population-level impacts to wild species, so a moderate deductive score of –4 out of –10 is given for Factor 9X – Wildlife and Predator Mortality. Because predator controls are not generally applied on the integrated shrimp-mangrove systems, these are not given any deduction (0 out of –10) for Factor 9X – Wildlife and Predator Mortality.

Criterion 10X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of species other than the principal farmed species unintentionally transported during live animal shipments.

This is an "exceptional" criterion that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score.

Criterion 10X Summary

Giant tiger prawn – Integrated shrimp-mangrove pond systems and extensive pond systems

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Whiteleg shrimp – Intensive pond systems

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	0.00	
F10Xb Biosecurity of source/destination	6.00	
C10X Escape of unintentionally introduced species Final Score	**–4.00**	**YELLOW**

Brief Summary

Giant tiger prawn is native to Vietnam, and in addition to passive stocking during pondwater exchanges, domestic hatchery-raised seed supplements both extensive production systems. Therefore, neither extensive systems nor integrated farming systems rely on international or trans-waterbody shrimp movements, and both giant tiger prawn systems score 10 out of 10 for Criterion 10X – Escape of Unintentionally Introduced Species. Whiteleg shrimp is not native to Vietnam; in 2009, 20% of the broodstock in Vietnam was imported from biosecure U.S. broodstock centers and 80% from "poor quality" Asian (most likely Chinese) broodstock centers, but current data suggest that the contribution from U.S. facilities may have increased substantially. Whiteleg shrimp farming therefore relies 100% on imported broodstock, resulting in a score of 0 out of 10 for Factor 10Xa. The mix of highly biosecure broodstock supplied from the U.S. with less-biosecure regional sources, in conjunction with reasonable, farm-based biosecurity measures (e.g., harvest water-exchange), results in a moderate score of 6 out of 10 for Factor 10Xb. The scores for Factors 10Xa and 10Xb are combined to result in a total deductive score of –4 out of –10 for whiteleg shrimp for Criterion 10X – Escape of Unintentionally Introduced species.

Justification of Ranking

Factor 10Xa International or trans-waterbody live animal shipments

Giant tiger prawn

Giant tiger prawn is native to Vietnam. Seed used in both extensive production systems are produced domestically; they are either collected from local waterways when the ponds are filled or hatchery-raised seed spawned by wild-caught broodstock. Although detailed information was not available on the status of Vietnamese broodstock populations, the NACA (2005) best management practices (BMPs) for hatcheries in Vietnam recommend that broodstock should be harvested using gill and trap nets and from "clean, deep water (30–60m) as far as possible from the influence of the coast." In 2015, Yamasaki (pers. comm. 2016) reported that Vietnam imported 6,000 specific pathogen free (SPF) giant tiger prawn broodstock from Hawaii, but such importation is not considered to be representative of giant tiger prawn production in Vietnam. Because there is no apparent reliance on international or trans-waterbody shrimp movements, both giant tiger prawn systems score 10 out of 10 for Factor 10Xa.

Whiteleg shrimp

Whiteleg shrimp only use hatchery-raised seed from domesticated broodstock (Joffre and Bosma 2009). Of whiteleg shrimp broodstock in Vietnam, 100% are imported from either the United States or Asia (most likely China) (Kawahigashi 2009) (Hambrey Consulting 2009) (pers. comm., Yamasaki 2016). This results in a score of 0 out of 10 for Factor 10Xa.

Factor 10Xb Biosecurity of source and destination

Giant tiger prawn

For giant tiger prawn, there are no international or trans-waterbody movements and Factor 10Xa is scored 10 out of 10, so Factor 10Xb, the biosecurity of the source and destination of such movements, does not need to be assessed.

Whiteleg shrimp

The available information suggests that, in 2009, 20% of whiteleg shrimp broodstock in Vietnam was imported directly from the United States and the other 80% from Chinese broodstock centers, which were initially supplied by the United States. But in 2015, Yamasaki (pers. comm., 2016) reported that Vietnam imported 101,380 SPF broodstock from Hawaii, suggesting that the percentage from U.S. sources may have increased substantially. The majority of U.S. broodstock comes from Hawaii, and the requirements for Hawaiian SPF broodstock are quite stringent, including 2 years of disease-free testing for a wide range of pathogens (SOH 2015). Required tests include for IHHNV, WSSV, TSV, YHV, IMNV, BP, monodon baculovirus (MBV), necrotizing hepatopancreatitis (NHP), and AHPNS, with potential for testing to include Mourilyan virus (MoV), hepatopancreatic parvovirus (HPV), and *Enterocytozoon hepatopenaei* (EHP) if the company wishes (pers. comm., Yamasaki 2016). These broodstock sources are considered fully biosecure; however, there is no clear evidence that the Chinese sources are similarly biosecure, particularly because Hambrey Consulting (2009) describe the supplied product as “low quality.” It is expected that any broodstock facility would at least limit water exchange, so the score for Factor 10Xb is 6 out of 10 for the biosecurity of the source of animal movements.

Intensive whiteleg shrimp farms in Vietnam apply some biosecurity measures, including limited water exchange (0%–3% daily). Circular No. 4512010rrT-BNNPTNT of July 22, 2010 requires that intensive farms:

- Treat influent to remove disease germs
- Improve pond beds
- Leave ponds fallow for one month after each production cycle
- Effluent must also be treated prior to discharge into the environment
- Farms must develop shrimp health management plans
- Dead and moribund shrimp must be removed and treated
- Staff and equipment must be disinfected before being used in a different pond
- All stocked PLs must come from approved sources and been certified to have passed a quarantine period

These are strong biosecurity measures, but questions remain about the level of legal compliance in Vietnam. Thus, a score of 6 out of 10 for the biosecurity of the destination (farm) is given.

Because the biosecurity of the source and the destination are scored equally, the final score is 6 out of 10 for Factor 10Xb.

The scores for Factors 10Xa and 10Xb are combined to result in a total deductive score of –4 out of –10 for whiteleg shrimp for Criterion 10X – Escape of Unintentionally Introduced Species.

Conclusions and Final Score

Giant tiger prawn farming in Vietnam does not appear to rely on international or trans-waterbody animal movements, so the final score is 0 out of –10 for Criterion 10X – Escape of Unintentionally Introduced Species. In contrast, there is evidence that all Vietnamese whiteleg shrimp farming depends on such movements. Because both the source (broodstock production facilities) and destination (growout farms) have moderate biosecurity, the final score for whiteleg shrimp for Criterion 10X – Escape of Unintentionally Introduced Species is –4 out of –10.

Overall Recommendation

The overall recommendation is as follows:

The overall final score is the average of the individual criterion scores (after the two exceptional scores have been deducted from the total). The overall ranking is decided according to the final score, the number of red criteria, and the number of critical scores as follows:

– **Best Choice** = Final score ≥6.6 AND no individual criteria are Red (i.e. <3.3)
– **Good Alternative** = Final score ≥3.3 AND <6.6, OR Final score ≥ 6.6 and there is one individual "Red" criterion.
– **Red** = Final score <3.3, OR there is more than one individual Red criterion, OR there is one or more Critical score.

Giant tiger prawn

Penaeus monodon

Vietnam

Integrated shrimp-mangrove ponds

Criterion	Score (0-10)	Rank	Critical?
C1 Data	4.38	YELLOW	
C2 Effluent	10.00	GREEN	NO
C3 Habitat	2.47	RED	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	6.00	YELLOW	NO
C7 Disease	5.00	YELLOW	NO
C8 Source	5.00	YELLOW	
C9X Wildlife mortalities	0.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**42.84**		
Final score	**5.36**		

OVERALL RANKING

Final Score	5.36
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	NO

FINAL RANK
RED

Giant tiger prawn

Penaeus monodon

Vietnam

Extensive shrimp ponds

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.44	YELLOW	
C2 Effluent	10.00	GREEN	NO
C3 Habitat	2.47	RED	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	6.00	YELLOW	NO
C7 Disease	5.00	YELLOW	NO
C8 Source	0.00	RED	
C9X Wildlife mortalities	–4.00	YELLOW	NO
C10X Introduced species escape	0.00	GREEN	
Total	**32.90**		
Final score	**4.11**		

OVERALL RANKING

Final Score	4.11
Initial rank	YELLOW
Red criteria	3
Interim rank	RED
Critical Criteria?	NO

FINAL RANK
RED

Whiteleg shrimp

Litopenaeus vannamei

Vietnam

Intensive

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.33	YELLOW	
C2 Effluent	6.00	YELLOW	NO
C3 Habitat	2.47	RED	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	5.78	YELLOW	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	5.00	YELLOW	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	–4.00	YELLOW	NO
C10X Introduced species escape	–4.00	YELLOW	
Total	**28.58**		
Final score	**3.57**		

OVERALL RANKING

Final Score	3.57
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	NO

FINAL RANK
RED

Acknowledgements

Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch would like to thank the consulting researchers and co-authors of this report Matthew Thompson, Cyrus Ma, and Lee Cocker as well as the government, academic, and industry experts who reviewed this document and who wish to remain anonymous.

References

A G Food Commodities (2016). Vietnam Sea Fishmeal 60%. Accessed 10/1/2016. Available at: http://agrocommodityasia.com/shop/animal-protein/fishmeal/vietnam-sea-fishmeal-60/

Alongi, D. M. (2008). "Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change." Estuarine, Coastal and Shelf Science 76(1): 1-13.

Auffrey, R. (2011).Roger Berkowitz & Vietnam Shrimp Farms. The Passionate Foodie. 6 May 2011. Available at: http://passionatefoodie.blogspot.com/2011/05/roger-berkowitz-vietnam-shrimp-farms.html

Balakrishnan, G., Peyail, S., Ramachandran, K., Theivasigamani, A., Savji, K. A., Chokkaiah, M., & Nataraj, P. (2011). Growth of cultured White Leg Shrimp Litopenaeus vannamei (Boone 1931) in different stocking density.Advances in Applied Science Research, 2(3), 107-113.

Barbier, Edward B., Evamaria W. Koch, Brian R. Silliman, Sally D. Hacker, Eric Wolanski, Jurgenne Primavera, Elise F. Granek et al. (2008) "Coastal ecosystem-based management with nonlinear ecological functions and values." *science* 319, no. 5861: 321-323.

BioAqua.vn. (2014). 5 provinces reported the highest yield in shrimp farming. Bioaqua VietNam. 12 September 2014. Available at: http://bioaqua.vn/en/5-provinces-reported-the-highest-yield-in-shrimp-farming.

Boone. (1931). Bulletin of the American Museum of Natural History, 63:173.

Bosma, R. H., Nguyen, T. H., Siahainenia, A. J., Tran, H. T., & Tran, H. N. (2014). Shrimp-based livelihoods in mangrove silvo-aquaculture farming systems. *Reviews in Aquaculture*.

Boyd, C.E., Tucker, C.S., McNevin, A, Bostick, K., and Clay, J. (2007). Indicators of resource use efficiency and environmental performance in fish and crustacean aquaculture. Reviews in Fisheries Science. 15: 327-360.

Bridson, P. (2013). Black tiger shrimp, *Penaeus monodon* (and secondary native Penaeid and Metapenaeid shrimp species), Ca Mau Province of Southern Vietnam and other areas of Southeast Asia. Seafood Watch Report (19 February 2013). Monterey Bay Aquarium. Available at: http://www.seafoodwatch.org/-/m/sfw/pdf/reports/mba_seafoodwatch_selvablacktigershrimpreport.pdf

Briggs, M. (2006). Cultured Aquatic Species Information Programme. *Penaeus vannamei*. Accessed 9/29/13. Available at: www.fao.org/fishery/culturedspecies/Litopenaeus_vannamei/en

Briggs, M., Funge-Smith, S., Subasinghe, R., & Phillips, M. (2004). Introductions and movement of *Penaeus vannamei* and *Penaeus stylirostris* in Asia and the Pacific. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific, RAP publication 2004/10

Briggs, M. R. P., & Funge-Smith, S. (1994). Unsustainable shrimp culture—causes and potential solutions from experience in Thailand. *Development of Strategies for Sustainable Shrimp Farming. Report to the Overseas Development Administration, Research Project*, *4751*.

Bush, S., P. van Zwieten, et al. (2010). "Scenarios for Resilient Shrimp Aquaculture in Tropical Coastal Areas." Ecology and Society 15(2): 15.

Chang, Y., Liu, W., Chen, T., Chan, T., Liu, K., Chuang, J., Kou, G., Lo, C., & Wang, H. (2012). Feeding hermit crabs to shrimp broodstock increases their risk of WSSV infection. Dis. Aquat. Org. 98: 193–199

Clough, B., Johnston, D., Xuan, T. T., Phillips, M. J., Pednekar, S. S., Thien, N. H., ... & Thong, P. L. (2002). Silvofishery farming systems in Ca Mau province, Vietnam. *The World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion, Published by the Consortium*.

Davis, D. A., Amaya, E., Venero, J., Zelaya, O., & Rouse, D. B. (2006). A case study on feed management to improving production and economic returns for the semi-intensive pond production of Litopenaeus vannamei. In *Avances en Nutrición Acuícola VIII. Memorias del Octavo Simposio Internacional de Nutrición Acuícola* (Vol. 15).

Directorate of Fisheries. (2015). Culture management conference and prevention of disease in farmed shrimp in brackish water. Directorate of Fisheries of Vietnam. Available at: http://www.fistenet.gov.vn/e-nuoi-trong-thuy-san/b-nuoi-thuy-san/hoi-nghi-quan-ly-nuoi-va-phong-chong-dich-benh-tren-tom-nuoi-nuoc-lo.

Duijn, A. P. van, Beukers, R., & van der Pijl, W. (2012). *The Vietnamese seafood sector: a value chain analysis* (p. 88). CBI/LEI, part of Wageningen UR.

Food and Agriculture Organization of the United Nations (FAO). (2005). Cultured Aquatic Species Information Programme. Penaeus monodon. Cultured Aquatic Species Information Programme. Text by Kongkeo, H. In:FAO Fisheries and Aquaculture Department [online]. Rome. Updated 29 July 2005. Available at: www.fao.org/fishery/culturedspecies/Penaeus_monodon/en

Food and Agriculture Organization of the United Nations (FAO) (2006). Cultured Aquatic Species Information Programme. Penaeus vannamei. Cultured Aquatic Species Information Programme. Text by Briggs, M. In:FAO Fisheries and Aquaculture Department [online]. Rome. Updated 7 April 2006. Available at: http://www.fao.org/fishery/culturedspecies/Penaeus_vannamei/en

Food and Agriculture Organization of the United Nations (FAO) (2011). Decree No. 29/2011/ND-CPofApril18, 2011. English translation. Accessed 9/5/16. Available at: http://faolex.fao.org/docs/pdf/vie107003.pdf

Food and Agriculture Organization of the United Nations (FAO) (2016a). "AGP - Fertilizer Specifications." FAO Plant nutrition. Retrieved 22 March 2016, from http://www.fao.org/agriculture/crops/core-themes/theme/spi/plantnutrition/fertspecs/en/.

Food and Agriculture Organization of the United Nations (FAO) (2016b). Fisheries and Aquaculture Information and Statistics Service. Accessed 10/17/2016

Food and Agriculture Organization of the United Nations (FAO) (2016c) Introduced Species Fact Sheets. *Penaeus vannamei* introduced to Viet Nam from America, China. Available at: www.fao.org/fishery/introsp/3811/en

Food and Agriculture Organization of the United Nations (FAO). 2011. Review of the state of world marine Fishery resources. FAO Fisheries and Aquaculture Technical Paper No. 569. Rome, FAO. 2011. 334 pp.

Food and Agriculture Organization of the United Nations (FAO). (1986). Shrimp Culture: Pond Design, Operation and Management. NACA Training Manual Series No. 2. Available at: http://www.fao.org/3/contents/76b2641d-29e4-51b0-b9e5-6ca46beb0d9f/AC210E00.htm

Food and Drug Administration (2016). Accessed 10/17/2017. Import Refusal Report. Available at : www.accessdata.fda.gov/scripts/importrefusals

Farfante, I. P., & Kensley, B. (1997). *Penaeoid and sergestoid shrimps and prawns of the world. Keys and diagnoses for the families and genera*. Editions du Museum national d'Histoire naturelle.

Flegel, T. W. (2007). "The Right to Refuse Revision in the Genus Penaeus." Aquaculture 264(1-4): 2-8.

Fluech, B. and Krimsky, L. (2011). Wild vs. Farmed Shrimp: The choice is yours. Accessed 8/24/13. Available at: collier.ifas.ufl.edu/SeaGrant/pubs/Shrimp%20Fact%20Sheet.pdf

Goessens, A., Satyanarayana, B., Van der Stocken, T., Quispe Zuniga, M., Mohd-Lokman, H., Sulong, I., Dahdouh-Guebas, F., 2014. Is Matang mangrove forest in Malaysia sustainably rejuvenating after more than a century of conservation and harvesting management? PLoS One 9 (8), e105069.

Green, B. W., Teichert-Coddington, D. R., Boyd, C. E., Harvin, J. L., Corrales, H. L., Zelaya, R., & Ramirez, E. (1997). The effects of pond management strategies on nutrient budgets, Honduras. *Pond Dynamics/Aquaculture Collaborative Research Support Program, Fourteenth Annual Technical Report. PD/A CRSP, Office of International Research and Development, Oregon State University, Corvallis, OR*, 8-121.

GSO. (2012). General Statistics Office. Results of the 2011 Rural, Agricultural and Fisheries Census. Vietnam GSO, Statistical Publishing House, 2012 http://www.gso.gov.vn/default_en.aspx?tabid=477&idmid=4&ItemID=13399

GSO. (2015). General Statistics Office. Last modified March 3, 2015. Available at: http://www.gso.gov.vn/default. aspx?tabid=430&idmid=3.

GSO. (2016). General Statistics Office. Results for shrimp aquaculture production (mt) from 2010-2014. Statistical Documentation and Service Centre. Accessed 8 March 2016. Available at: http://www.gso.gov.vn/default_en.aspx?tabid=778

Gunalan, B. (2015). Semi-intensive Culture Techniques for Shrimp Farming. In Advances in Marine and Brackishwater Aquaculture (pp. 151-162). Springer India.

Ha, T.T.P., 2012. Resilience and Livelihood Dynamics of Shrimp Farmers and Fishers in the Mekong Delta, Vietnam. PhD Thesis, Wageningen University, The Netherlands, 2012

Ha, T.T.T., van Dijk, H., Bosma, R. and Sinh, L.X. (2010). Livelihood Capabilities and Pathways of Shrimp Farmers in the Mekong Delta, Vietnam. Aquaculture Economics & Management, peer review copy. Manuscript ID: UAQM-2010-0031.R2, 2010

Ha, Tran Thi Thu; Bush, Simon R.; Mol, Arthur P.J.; van Dijk, Han (2012): Organic coasts? Regulatory challenges of certifying integrated shrimp–mangrove production systems in Vietnam. In:*Journal of Rural Studies* 28 (4), p. 631–639.

Ha, Tran Thi Thu; van Dijk, Han; Bush, Simon R. (2012a): Mangrove conservation or shrimp farmer's livelihood? The devolution of forest management and benefit sharing in the Mekong Delta, Vietnam. In: *Ocean & Coastal Management* 69, p. 185–193.

Ha, T. T. T., van Dijk, H., & Visser, L. (2014). Impacts of changes in mangrove forest management practices on forest accessibility and livelihood: A case study in mangrove-shrimp farming system in Ca Mau Province, Mekong Delta, Vietnam. *Land Use Policy*, *36*, 89-101.

Hai, T. N., Phu, T. Q., and Ut, V. N. (2014). Shrimp Industry In Vietnam: Innovation toward sustainable development. XVI Congreso Ecuatoriano de Acuicultura and Aquaexpo. Available at: http://www.cna-ecuador.com/aquaexpo/2014/presentaciones/3-Tran_Ngoc_Hai.pdf

Hambrey Consulting. (2009). Risk profile of household scale production of Pangasius and shrimp in the Mekong Delta of Vietnam. Available at: http://www.hambreyconsulting.co.uk/Documents/Risk%20profile%20Pangasius%20shrimp%20%20Mekong%20HC.pdf

Hoa, N.D., 2009. Domestication of black tiger shrimp (Penaeus monodon) in recirculation systems in Vietnam. PhD thesis, Ghent University, Belgium.

Hong, P.N., 2003. Mangrove forests in Vietnam e present status and challenges. In: International Symposium on Conservation and Wise Use of Mangroves in Southeast Asia, Brunei Darussalam, 6-8 October 2003.

Hussain, S.A., Badola, R., 2010. Valuing mangrove benefits: contribution of mangrove forests to local livelihoods in Bhitarkanika Conservation Area, East Coast of India. Wetl. Ecol. Manag. 18, 321e331.

Hung, L.T. and Huy, H.P.V. (2007). Analysis of feeds and fertilizers for sustainable aquaculture development in Viet Nam. In M.R. Hasan, T. Hecht, S.S. De Silva and A.G.J. Tacon (eds). Study and analysis of feeds and fertilizers for sustainable aquaculture development. FAO Fisheries Technical Paper. No. 497. Rome, FAO. pp. 331–361.

Hung, L.T. and Quy, O.M. (2013). On farm feeding and feed management in whiteleg shrimp (*Litopenaeus vannamei*) farming in Viet Nam. In M.R. Hasan and M.B. New, eds. On-farm feeding and feed management in aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 583. Rome, FAO. pp. 337–357.

IUCN. (2016). Red List Search. http://www.iucnredlist.org/

IUCN. (2013). Not seeing the mangrove forest for the trees?. International Union for Conservation of Nature. Available at: http://www.iucn.org/news_homepage/news_by_date/?14002/Not-seeing-the-mangrove-forest-for-the-trees

Jonell, M., & Henriksson, P. J. G. (2015). Mangrove–shrimp farms in Vietnam—Comparing organic and conventional systems using life cycle assessment.*Aquaculture*, *447*, 66-75.

Jory, D. E., Cabrera, T. R., Dugger, D. M., Fegan, D., Lee, P. G., *et al.* (2001). A global overview of current shrimp feed management: status and perspectives. In: *The New Wave*, *Proceedings of the Special Session on Sustainable Shrimp Culture* (Ed. by C. L. Browdy & D. E. Jory), pp. 104–52. Aquaculture 2001, The World Aquaculture Society, Baton Rouge, LA.

Kawahigashi (2010). Overview of P. vannamei Culture and Broodstock Domestication in Asia. Available at: www.spc.int/aquaculture

Kongkeo, H. (2005). Cultured Aquatic Species Information Programme. *Penaeus monodon*. Accessed 12/29/13. Available at: www.fao.org/fishery/culturedspecies/Penaeus_monodon/en

Lan, N.T.P. (2013). Social and ecological challenges of market-oriented shrimp farming in Vietnam. SpringerPlus 2013, 2:675.

Lightner, D.V. (2011). Virus diseases of farmed shrimp in the Western Hemisphere (the Americas): a review. J Invertebr Pathol. 2011 Jan;106(1):110-30.

Le Dinh, H. (2017). Personnal Communication.

Lightner, D.V., Redman, R.M., Pantoja, C.R., Noble, B.L., Tran, L. (2012). Early Mortality Syndrome Affects Shrimp In Asia. Global Aquaculture Advocate. 15(1): 40. Available at: www.gaalliance.org/mag/2012/Jan-Feb/download.pdf

Lorenzen, K. (1999). Nitrogen recovery from shrimp pond effluent: dissolved nitrogen removal has greater overall potential than particulate nitrogen removal, but requires higher rates of water exchange than presently used. *Aquaculture Research*, *30*(11-12), 923-927.

McNally, R., A. McEwin, and T. Holland. (2011). The Potential for Mangrove Carbon Projects in Vietnam. Ha Noi, Vietnam: SNV-Netherlands Development Organisation.

Minh, T. H., A. Yakupitiyage and D. J. Macintosh. (2001). Management of the Integrated Mangrove-Aquaculture Farming Systems in the Mekong Delta of Vietnam. ITCZM Monograph No. 1, 24 pp.

Minhphu (2016). www.minhphu.com. Accessed 10/17/2016

Ministry of Agriculture and Rural Development (MARD). 2016. About MARD. Accessed 9/14/2016. Available at: www.mard.gov.vn/en/Pages/mandate.aspx?TabId=AboutMARD

Ministry of Natural Resources and Environment (MNRE). 2005. CIRCULAR No. 02/2005/IT-BTNMT of June 24,2005, guiding the implementation of the government's decree N~. 149/2004/ND-CP of July 27,2004, on the issuance of permits for water resource exploration, exploitation and use, or for discharge of wastewater into water sources. Available at: http://faolex.fao.org/docs/pdf/vie53444.pdf

Mukhopadhyay, R. (2014). Scourge below the surface. American Society for Biochemistry and Molecular Biology. February 2014. Available at: http://www.asbmb.org/asbmbtoday/201402/Shrimp/

Munasinghe, M. N., Stephen, C., Abeynayake, P., & Abeygunawardena, I. S. (2010). Shrimp farming practices in the Puttallam district of Sri Lanka: implications for disease control, industry sustainability, and rural development. Veterinary medicine international, 2010.

Murekezi, P. (2014). National Aquaculture Legislation Overview. Viet Nam. National Aquaculture Legislation Overview (NALO) Fact Sheets. Text by Murekezi, P. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 22 October 2014. Accessed 9/5/16. Available at: www.fao.org/fishery/legalframework/nalo_vietnam/en

NACA (2005). Better Management Practices (BMP) Manual for Black Tiger Shrimp (Penaeus monodon) Hatcheries in Viet Nam.

Nair, S. (2015). Shrimp Aquaculture in Ca Mau, Vietnam. *with Tanja Havemann*, 123. Available at: http://ecoagriculture.org/wp-content/uploads/2015/08/Steps-Toward-Green-Book-File-Final-for-Upload.pdf

Nga, B. T., and Tinh, H. Q. (2008). System of Forest-Shrimp in sustainable development coastal Mekong Delta. Journal of Science:10 6-13. Available at: http://sj.ctu.edu.vn/ql/docgia/download/baibao-5050/02_Bui%20Thi%20Nga%2006%2013%20R.pdf

Nhandan. (2015). US business eyes big projects in Thua Thien Hue province. Vietnam Breaking News. 28 October 2015. Available at: http://www.vietnambreakingnews.com/2015/10/us-business-eyes-big-projects-in-thua-thien-hue-province/

National Fisheries Institute (NFI) (2015). Top 10 Consumed Seafoods. Accessed 11/10/13. Available at: www.aboutseafood.com/about/about-seafood/top-10-consumed-seafoods

Nikolik, G. and Kumar, P. (2013). Shrimp in a Crimp. Challenges and Expectations in Global Shrimp Aquaculture. Rabobank International.

Parr, M. (2013). Shrimp Farming: Global Value, Local Challenges. IUCN PPT presentation in Responsible Shrimp Culture Improvement Project (RSCIP) in Viet Nam: Findings, Funding and the Future for Small-Scale Farmers. Conference summary report, 20-21 December, 2012, Hanoi, Vietnam.

Phillips, M.J., Enyuan, F., Gavine, F., Hooi, T.K., Kutty, M.N., Lopez, N.A., Mungkung, R., Ngan, T.T., White, P.G., Yamamoto, K. and Yokoyama, H. (2009) Review of environmental impact assessment and monitoring in aquaculture in Asia-Pacific. In FAO. Environmental impact assessment and monitoring in aquaculture.FAO Fisheries and Aquaculture Technical Paper. No. 527. Rome, FAO. pp. 153–283.

Omoto (2012). Small-scale producers and the governance of certified organic seafood production in Vietnam's Mekong Delta. Ph D. Thesis. Waterloo University. Available at: https://uwspace.uwaterloo.ca/bitstream/handle/10012/7078/omoto;jsessionid=199DE289DD2C78E3E510FBC12E9A96A5?sequence=1

Quach, A., Murray, F., & Morrison-Saunders, A. (2015). Perspectives of farmer and experts in Ca Mau, Vietnam on the effects of climate change on shrimp production. *International Journal of Environmental Science and Development*, *6*(10), 718-726.

Quoc, T. H. (2016). Productivity and Natural Resource Dependence in the Vietnamese Shrimp Aquaculture Sector. Aquaculture 2016 Conference Presentation. 26 February 2016.

RASSF Portal (2016). https://webgate.ec.europa.eu/

Son, N.T., Chen, C., Chang, N., Chen, C, Chang, L., and Thanh, B. (2016). Mangrove Mapping and Change Detection in Ca Mau Peninsula, Vietnam, Using Landsat Data and Object-Based Image Analysis. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. 8(2): 2015

State of Hawaii (SOW) (2015). Animal Industry Division.SPF Broodstock. Available at: hdoa.hawaii.gov/ai/aquaculture-and-livestock-support-services-branch/spf-shrimp-broodstock/

Stevenson, N.J. (1997). Abandoned Shrimp Ponds: Options for Redevelopment of Mangrove. Coastal Management. 25 (4) 423-425.

Tacon, A. G., Nates, S. F., & McNeil, R. J. (2004). Dietary feeding strategies for marine shrimp: a review. *Avances en Nutrición Acuícola VII. VII Simposium Internacional de Nutrición Acuícola. Memorias*, 16-19.

Tendencia, E.A., Bosma, R.H., Primavera, J.H., Verreth, J.A.J., 2012. Effect of different mangrove-to-pond area ratios on influent water quality and WSSV occurrence in Penaeus monodon semi-intensive farms using the greenwater culture technique. Aquaculture 362e363, 72e79. http://dx.doi.org/10.1016/j.aquaculture.2012.07.020.

Thu, K. (15 December 2015). Vietnam is Japan's Top Supplier for Frozen Raw Shrimp. Vietnam Association of Seafood Exporters and Producers (VASEP). Article available at: http://seafood.vasep.com.vn/seafood/50_10940/vietnam-is-japans-top-supplier-for-frozen-raw-shrimp.htm

Thu, K. (23 November 2015a). Vietnam shrimp exports: Hoping for the next months. Vietnam Association of Seafood Exporters and Producers (VASEP). Article available at: http://seafood.vasep.com.vn/seafood/50_10927/vietnam-shrimp-exports-hoping-for-the-next-months.htm

Thu, K. (14 January 2016). Vietnam shrimp exports 2015: Challenges and opportunities

Thuyet, B.D. (2012). Environmental impacts of coastal shrimp farming in North Vietnam. RIA1's Newsletter. Issue 7 (Jul - Sep 2012).

Tran NH (2005) Effects of mangrove leaf litters on the integrated mangrove - shrimp farming systems in Ca Mau Province, Vietnam. PhD thesis Asian Institute of Technology, Thailand.

Tran, N. H., Pham, M. D., Vo, N. S., Truong, H. M., and Nguyen, T. P. (2015). Innovation in Seed Production and Farming of Marine Shrimp in Vietnam. World Aquaculture Magazine. World Aquaculture Society. Volume 46, Number 1, Page 32

Troell, M. (2009). Integrated marine and brackishwater aquaculture in tropical regions: research, implementation and prospects. *Integrated mariculture: a global review. FAO Fisheries and Aquaculture Technical Paper*, *529*, 47-131.

Tuan, M.S (1996) Building up the strategy for mangrove management in Vietnam, p. 35, in Proceedings of the ECOTONE V Regional Seminar: Community Participation In Conservation, Sustainable Use and Rehabilitation of Mangroves In Southeast Asia, Ho Chi Minh City, Vietnam, 8-12 January,1996. Mangrove Ecosystem Research Centre (MERC), Vietnam National University, Vietnam

Uchida, K., Konishi, Y., Harada,K., Okihashi, M., Yamaguchi,T., Do, M.H.N., Bui, L.T., Nguyen, T.D., Nguyen, P.D., Khong, D.T., Tran, H.T., Nguyen, T.N., Le, H.V., Chau, V.V., Dao, K.T.V., Nguyen, H.T.N., Kajimura, K., Kumeda, Y., Pham, K.T., Pham, K.N., Bui, C.T., Vien, M.Q., Le, N.H., Dang, C.V., Hirata, K., Yamamoto, Y. (2016). Monitoring of Antibiotic Residues in Aquatic Products in Urban and Rural Areas of Vietnam. J. Agric. Food Chem., 2016, 64 (31): 6133–6138

Urch, M. (2015). The state of things and what's to come for Vietnamese shrimp

Vietnam Association of Seafood Exporters and Producers (VASEP). Available at: http://www.seafoodsource.com/all-commentary/the-state-of-things-and-what-s-to-come-for-vietnamese-shrimp

USDA. (2016). U.S. shrimp imports, volume by selected sources. Last updated 7 March 2016. Available at: http://www.ers.usda.gov/datafiles/Aquaculture/Trade/AquacultureTradeFull.xls

VASEP. (2014). Characteristics of the Sector. Vietnam Association of Seafood Exporters and Producers (VASEP). Available at: http://seafood.vasep.com.vn/669/onecontent/sector-profiles.htm. Retrieved 29 January 2016.

VASEP. (2016). Positive signs for Vietnam shrimp production and exports in first 2 months. .

Vietnam Association of Seafood Exporters and Producers (VASEP). Available at: http://seafood.vasep.com.vn/seafood/50_11045/positive-signs-for-vietnam-shrimp-production-and-exports-in-first-2-months.htm

VASEP. (2016a). VietG.A.P. Application to Raise Seafood Export Value. Vietnam Association of Seafood Exporters and Producers (VASEP). Available at: http://seafood.vasep.com.vn/whybuy/657_11051/vietgap-application-to-raise-seafood-export-value.htm.

VCC. (2013). Vietnam Certification Center (VCC) website. Available at: http://www.quacert.gov.vn/en/aquaculture.iso269.html

Vietnam Law & Legal Forum (VLLF). (2010). Offical Gazette. Circular No. 4512010rrT-BNNPTNT of July 22, 2010, providing for conditions on food safety and hygiene-guaranteed intensive tiger shrimp and white-leg shrimp rearing establishments and zones. Issue 03/August 2010. Available at: faolex.fao.org/docs/pdf/vie99782.pdf

VNN. (2014). Shrimp project helps create 'organic coast.' VietNamNet Online Newspaper. Available at: http://english.vietnamnet.vn/fms/environment/93714/shrimp-project-helps-create--organic-coast-.html

Vo, Q.T. (2013) Valuation of Mangrove Ecosystems along the Coast of the Mekong Delta in Vietnam an approach combining socio-economic and remote sensing methods. PhD Dissertation Department of Geography Faculty of Math and Natural Science Kiel University, Kiel, Germany.

Walker, P. J., & Mohan, C. V. (2009). Viral disease emergence in shrimp aquaculture: origins, impact and the effectiveness of health management strategies. Reviews in Aquaculture, 1(2), 125–154.

White, P., Phillips, M.J. & Beveridge, M.C.M. (2013). Environmental impact, site selection and carrying capacity estimation for small-scale aquaculture in Asia. *In* L.G. Ross, T.C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez, eds. *Site selection and carrying capacities for inland and coastal aquaculture,* pp. 231–251. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 282 pp.

World Organization for Animal health (OIE) (2016a). OIE-Listed diseases, infections and infestations in force in 2016).

World Organization for Animal health (OIE). (2016b). Vietnam. Diseases present in the Country. WAHIS Interface. Animal Health Situation.

World Bank, NACA, WWF, & FAO. (2006). The international principles for responsible shrimp farming: shrimp farming and the environment (7 March 2006 draft). www.enaca.org/shrimp Accessed 30.05.2006.

World Health Organization (WHO). (2017). Critically Important Antimicrobials for Human Medicine 5th Revision 2016. Available at: http://apps.who.int/iris/bitstream/10665/255027/1/9789241512220-eng.pdf?ua=1

Yamasaki, L. (2016). Personal Communication.

Zavalloni M, Groeneveld RA, van Zwieten PAM (2014) The role of spatial information in the preservation of the shrimp nursery function of mangroves: a spatially explicit bio-economic model for the assessment of land use trade-offs. Journal of Environmental Management 143: 17‑25.

About Seafood Watch®

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch®'s sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer
Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[3] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

The following **guiding principles** illustrate the qualities that aquaculture must possess to be considered sustainable by the Seafood Watch program:

Seafood Watch will:

- Support data transparency and therefore aquaculture producers or industries that make information and data on production practices and their impacts available to relevant stakeholders.
- Promote aquaculture production that minimizes or avoids the discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.
- Promote aquaculture production at locations, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats without unreasonably penalizing historic habitat damage.
- Promote aquaculture production that by design, management or regulation avoids the use and discharge of chemicals toxic to aquatic life, and/or effectively controls the frequency, risk of environmental impact and risk to human health of their use
- Within the typically limited data availability, use understandable quantitative and relative indicators to recognize the global impacts of feed production and the efficiency of conversion of feed ingredients to farmed seafood.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild fish or shellfish populations through competition, habitat damage, genetic introgression, hybridization, spawning disruption, changes in trophic structure or other impacts associated with the escape of farmed fish or other unintentionally introduced species.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.
- promote the use of eggs, larvae, or juvenile fish produced in hatcheries using domesticated broodstocks thereby avoiding the need for wild capture

3 "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates.

- recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving practices for some criteria may lead to more energy intensive production systems (e.g. promoting more energy-intensive closed recirculation systems)

Once a score and rank has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choices/Green: Are well managed and caught or farmed in environmentally friendly ways.

Good Alternatives/Yellow: Buy, but be aware there are concerns with how they're caught or farmed.

Avoid/Red: Take a pass on these. These items are overfished or caught or farmed in ways that harm other marine life or the environment.

Appendix 1 - Data points and all scoring calculations

This is a condensed version of the criteria and scoring sheet to provide access to all data points and calculations. See the Seafood Watch Aquaculture Criteria document for a full explanation of the criteria, calculations and scores. Yellow cells represent data entry points.

Giant tiger prawn - Integrated shrimp-mangrove pond systems

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	5	5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	5	5
Chemical use	Yes	2.5	2.5
Feed	No	Not relevant	n/a
Escapes, animal movements	Yes	5	5
Disease	Yes	5	5
Source of stock	Yes	2.5	2.5
Predators and wildlife	Yes	2.5	2.5
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**35**

C1 Data Final Score	4.375	YELLOW

Criterion 2: Effluents

Effluent Rapid Assessment

C2 Effluent Final Score	**10.00**	**GREEN**

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**1**

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Moderately	0.5
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Moderately	0.5
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	No	0
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Moderately	0.5
		1.75

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Moderately	0.5
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Partly	0.25
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Moderately	0.5
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	Moderately	0.5
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Partly	0.25
		2

F3.2 Score (2.2a*2.2b/2.5)	**1.40**

C3 Habitat Final Score	**1.13**	**RED**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	0.00	
C4 Chemical Use Final Score	0.00	RED
Critical?	NO	

Criterion 5: Feed

C5 Feed Final Score		10.00	GREEN
Critical?	NO		

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	5

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**5**

6.1b. Invasiveness

Part A – Native species

Score	4

Part B – Non-Native species

Score	**0**

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	To some extent
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	No

Do escapees have some other impact on other native species or habitats?	No
	5

F 6.1b Score	**8**

Final C6 Score	**6.00**	**YELLOW**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	5.00	
C7 Disease; pathogen and parasite Final Score	**5.00**	**YELLOW**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	50	
C8 Source of stock Final Score	**5**	**YELLOW**

Criterion 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**0.00**	**GREEN**
Critical?	NO	

Criterion 10X: Escape of unintentially introduced species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	0.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Giant tiger prawn – Extensive pond systems

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	5	5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	5	5
Chemical use	Yes	2.5	2.5
Feed	No	Not relevant	n/a
Escapes, animal movements	Yes	0	0
Disease	Yes	5	5
Source of stock	Yes	2.5	2.5
Predators and wildlife	Yes	0	0
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**27.5**

C1 Data Final Score	3.4375	YELLOW

Criterion 2: Effluents

Effluent Rapid Assessment

C2 Effluent Final Score	**10.00**	**GREEN**

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**1**

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Moderately	0.5
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Moderately	0.5

4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	No	0
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Moderately	0.5
		1.75

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Moderately	0.5
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Partly	0.25
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Moderately	0.5
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	Moderately	0.5
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Partly	0.25
		2

F3.2 Score (2.2a*2.2b/2.5)	**1.40**

C3 Habitat Final Score	**1.13**	**RED**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	**0.00**	
C4 Chemical Use Final Score	**0.00**	**RED**
Critical?	NO	

Criterion 5: Feed

C5 Feed Final Score		**10.00**	**GREEN**
Critical?	NO		

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	**5**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**5**

6.1b. Invasiveness

Part A – Native species

Score	4

Part B – Non-Native species

Score	**0**

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	To some extent
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	No
Do escapees have some other impact on other native species or habitats?	No
	4

F 6.1b Score	**8**

Final C6 Score	**6.00**	**YELLOW**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	5.00	
C7 Disease; pathogen and parasite Final Score	**5.00**	**YELLOW**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	0	
C8 Source of stock Final Score	**0**	**RED**

Criterion 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**-4.00**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	0.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Whiteleg shrimp – Intensive pond systems

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	5	5
Effluent	Yes	5	5
Locations/habitats	Yes	5	5
Chemical use	Yes	2.5	2.5
Feed	Yes	5	5
Escapes, animal movements	Yes	0	0
Disease	Yes	5	5
Source of stock	Yes	2.5	2.5
Predators and wildlife	Yes	0	0
Other – (e.g. GHG emissions)	No	Not relevant	n/a
Total			**30**

C1 Data Final Score	3.33	YELLOW

Criterion 2: Effluents

Factor 2.1a - Biological waste production score

Protein content of feed (%)	40
eFCR	1.25
Fertilizer N input (kg N/ton fish)	0
Protein content of harvested fish (%)	17.8
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	80
N in each ton of fish harvested (kg)	28.48
Waste N produced per ton of fish (kg)	**51.52**

Factor 2.1b - Production System discharge score

Basic production system score	0.34
Adjustment 1 (if applicable)	-0.24
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score	**0.1**

2.2 – Management of farm-level and cumulative impacts and appropriateness to the scale of the industry

Factor 2.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Are effluent regulations or control measures present that are designed for, or are applicable to aquaculture?	Yes	1
2 - Are the control measures applied according to site-specific conditions and/or do they lead to site-specific effluent, biomass or other discharge limits?	Mostly	0.75
3 - Do the control measures address or relate to the cumulative impacts of multiple farms?	Moderately	0.5
4 - Are the limits considered scientifically robust and set according to the ecological status of the receiving water body?	Moderately	0.5
5 - Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	No	0
		2.75

Factor 2.2b - Enforcement level of effluent regulations or management

Question	Scoring	Score
1 - Are the enforcement organizations and/or resources identifiable and contactable, and appropriate to the scale of the industry?	Moderately	0.5
2 - Does monitoring data or other available information demonstrate active enforcement of the control measures?	No	0
3 - Does enforcement cover the entire production cycle (i.e. are peak discharges such as peak biomass, harvest, sludge disposal, cleaning included)?	No	0
4 - Does enforcement demonstrably result in compliance with set limits?	No	0
5 - Is there evidence of robust penalties for infringements?	No	0
		0.5

F2.2 Score (2.2a*2.2b/2.5)	**0.55**

C2 Effluent Final Score	**6.00**	**YELLOW**
	Critical?	NO

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**1**

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Moderately	0.5
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Moderately	0.5
4 - Are high-value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	No	0
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Moderately	0.5
		1.75

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Moderately	0.5
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Partly	0.25
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Moderately	0.5
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc?	Moderately	0.5
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Partly	0.25
		2

F3.2 Score (2.2a*2.2b/2.5)	**1.40**

C3 Habitat Final Score	**1.13**	**RED**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	0.00	
C4 Chemical Use Final Score	**0.00**	RED
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Factor 5.1a - Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	20
Fishmeal from by-products (%)	0
% FM	20
Fish oil inclusion level (%)	2
Fish oil from by-products (%)	0
% FO	2
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.25
FIFO fishmeal	1.11
FIFO fish oil	0.50
Greater of the 2 FIFO scores	1.11
FIFO Score	**7.22**

Factor 5.1b - Sustainability of the Source of Wild Fish (SSWF)

SSWF	-6
SSWF Factor	-0.666666667

F5.1 Wild Fish Use Score	**6.56**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	40
eFCR	1.25
Feed protein from NON-EDIBLE sources (%)	0
Feed protein from EDIBLE CROP soruces (%)	67

Protein OUTPUTS	
Protein content of whole harvested fish (%)	17.8
Edible yield of harvested fish (%)	67
Non-edible by-products from harvested fish used for other food production	50
Protein IN	40.42
Protein OUT	14.863
Net protein gain or loss (%)	-63.22769
Critical?	NO
F5.2 Net protein Score	**3.00**

5.3. Feed Footprint

5.3a Ocean area of primary productivity appropriated by feed ingredients per ton of farmed seafood

Inclusion level of aquatic feed ingredients (%)	22
eFCR	1.25
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	7.15

5.3b Land area appropriated by feed ingredients per ton of production

Inclusion level of crop feed ingredients (%)	78
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.25
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.37

Value (Ocean + Land Area)	**7.52**

F5.3 Feed Footprint Score	**7.00**

C5 Feed Final Score	**5.78**	**YELLOW**
	Critical?	**NO**

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	6

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture & Mortality Score	0
Factor 6.1a Escape Risk Score	**6**

6.1b. Invasiveness

Part A – Native species

Score	0

Part B – Non-Native species

Score	**0.5**

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	To some extent
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	No
Do escapees have some other impact on other native species or habitats?	No
	4

F 6.1b Score	**4.5**

Final C6 Score	**4.00**	**YELLOW**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	5.00	
C7 Disease; pathogen and parasite Final Score	**5.00**	**YELLOW**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock, natural (passive) settlement, or sourced from sustainable fisheries	100	
C8 Source of stock Final Score	**10**	**GREEN**

Criterion 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**-4.00**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	0.00	
F10Xb Biosecurity of source/destination	6.00	
C10X Escape of unintentionally introduced species Final Score	**-4.00**	**YELLOW**