Monterey Bay Aquarium
Seafood Watch®

Giant Tiger Prawn, Whiteleg Shrimp

Penaeus monodon, Litopenaeus vannamei

Indonesia

Ponds

December 10, 2015

Cyrus Ma – Seafood Watch

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.

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.

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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[1] 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.
- 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).

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

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.

Final Seafood Recommendation

Black Tiger Shrimp

Penaeus monodon

Indonesia

Extensive shrimp ponds

Criterion	Score (0-10)	Rank	Critical?
C1 Data	3.13	RED	
C2 Effluent	3.00	RED	NO
C3 Habitat	2.87	RED	NO
C4 Chemicals	4.00	YELLOW	NO
C5 Feed	10.00	GREEN	NO
C6 Escapes	5.00	YELLOW	NO
C7 Disease	2.00	RED	NO
C8 Source	0.00	RED	
C9X Wildlife mortalities	-5.00	YELLOW	NO
C10X Introduced species escape	0.00	GREEN	
Total	**24.99**		
Final score	**3.12**		

OVERALL RANKING

Final Score	3.12
Initial rank	RED
Red criteria	4
Interim rank	RED
Critical Criteria?	YES

FINAL RANK
RED

Whiteleg shrimp

Penaeus vannamei

Indonesia

Intensive shrimp ponds

Criterion	Score (0-10)	Rank	Critical?
C1 Data	4.17	YELLOW	
C2 Effluent	4.00	YELLOW	NO
C3 Habitat	3.00	RED	NO
C4 Chemicals	0.00	RED	NO
C5 Feed	5.14	YELLOW	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	3.00	RED	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	-5.00	YELLOW	NO
C10X Introduced species escape	-1.20	GREEN	
Total	**27.11**		
Final score	**3.39**		

OVERALL RANKING

Final Score	3.39
Initial rank	YELLOW
Red criteria	3
Interim rank	RED
Critical Criteria?	NO

FINAL RANK

RED

Scoring note –scores range from 0 to 10 where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Color ranks: red = 0 to 3.33, yellow = 3.34 to 6.66, green = 6.66 to 10. Criteria 9X and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects very poor performance. Two or more red criteria trigger a red final result.

Summary

The final numerical score for extensively farmed *Penaeus monodon* in Indonesia is 3.12 out of 10, where the presence of 4 red criteria (Effluent, Habitat, Chemicals, Disease, and Source of Stock) results in an overall Red “Avoid” recommendation. For intensively farmed *Litopenaeus vannamei*, the final numerical score is 3.39 out of 10, where the presence of 3 Red criterion (Habitat, Chemicals, Disease) results in an overall red “Avoid” recommendation.

Executive Summary

Giant tiger prawn (*Penaeus monodon*) and whiteleg shrimp (*Litopenaeus vannamei*) represent the two major shrimp species farmed in Indonesia. While the culture of native *P. monodon* first began in the 1960s in large, extensive brackish water ponds (locally known as *tambaks*), the introduction of laws legalizing the import of *L. vannamei* in 2001 has prompted a shift in shrimp culture toward greater stocking densities with a higher degree of system management to enhance production. Although extensive *P. monodon* farms currently comprise the bulk of the shrimp farming industry's land area in Indonesia, intensive production of *L. vannamei* has overtaken *P. monodon* in terms of product volume since 2007. According to the Indonesian Directorate General of Aquaculture, 126.6 mt of *P. monodon* and 411.7 mt of *L. vannamei* were produced in 2014.

In addition to peer-reviewed journals, literature by FAO, NACA, US-AID, ACIAR, and communications with industry experts are particularly important data sources for a range of subjects in this assessment. Nonetheless, cumulative effluent and habitat impacts, current chemical use, associated wildlife mortalities, and the broader ecological impacts of non-native shrimp introduction have been neither well-studied nor well-documented. Furthermore, while individual ASC audits of two sites within the CP Prima Group provide some farm-level data for intensively cultured *L. vannamei*, they are not considered to reflect the industry as a whole. Farm-level data for extensive *P. monodon* farms remains poor given the absence of publicly available certification audits or any regulatory environmental monitoring requirement for small-scale extensive farms. Overall, data accessibility and availability for extensive *P. monodon* farming and intensive *L. vannamei* farming in Indonesia is variable, depending on the subject matter, and is scored moderately or poorly based on current information availability. The final score for the Data Criterion is 3.13 out of 10 for *P. monodon* and 4.17 out of 10 for *L. vannamei*.

The Seafood Watch Effluent Criterion combines the total amount of waste released per ton of production with an assessment of applicable management measures and their implementation to provide a measure of the impact from discharged wastes. For extensive *P. monodon* farms, the total waste discharged (using nitrogen as a proxy) is estimated to be 68.17 kg N t^{-1}, and 39.68 kg N t^{-1} for intensive *L. vannamei* farms. Although the effluent discharged from shrimp farms is collected between farming cycles, the fate of sludge material disposed of offsite is currently unknown. Regarding regulatory management, consideration of the cumulative impacts from multiple farms is absent for *P. monodon* farms and is poorly addressed in the *L. vannamei* farming industry. There is no provision for public review of EIA documents and very little transparency in the EIA process for large farm sites over 50 ha in size. While farm clusters, which collectively form a combined 50 ha, are still subject to environmental assessment, the enactment of this legislation is not a legal requirement and smaller, non-fed farming operations (at least 75% of the Indonesian shrimp farming industry) are exempt from the EIA process. Furthermore, decentralized policy-setting practices in Indonesia have resulted in an ineffective environmental regulatory regime characterized by weak institutional support at local levels of government and inadequate enforcement. Overall, pond systems in Indonesia produce moderate impacts to the environment from effluent discharge. When combined with poor management of cumulative impacts, these conditions result in a final Criterion 2 – Effluent score of 3 out of 10 for extensively farmed *P. monodon* and 4 out of 10 for intensively farmed *L. vannamei*.

In Indonesia, shrimp aquaculture has historically been responsible for ~50% of the depletion in Indonesia's coastal mangrove forests (~750,000 ha). Although the shrimp farming industry currently represents the single largest historic cause of mangrove loss in Indonesia, very few new shrimp farms are being built in mangrove areas, as prospective *L. vannamei* farmers typically upgrade sites that were originally intended for *P. monodon* culture. Regarding habitat and farm siting management, inadequate EIA requirements and poor spatial planning laws have resulted in a regulatory framework that is unable to effectively manage or mitigate cumulative impacts. Nonetheless, ongoing habitat restoration efforts by various regional and international programs have resulted in the rehabilitation of 1,973 ha of mangroves per year. Combining the degree of habitat conversion with management effectiveness results in a Habitat Criterion score of 2.87 out of 10 for extensive *P. monodon* farms and a score of 3 out of 10 for intensive *L. vannamei* farms.

Shrimp farmers in Indonesia have relied on a wide variety of synthetic and natural chemicals and biological treatments to prevent and treat disease, to enhance the health status of the cultured species, and to improve pond conditions. While extensive *P. monodon* farmers typically do not apply medications and antibiotics during the production cycle, the use of pesticides, such as saponin and diazinon, result in impacts to non-target species in and around the farm site. For intensive *L. vannamei* culture, the widespread, prophylactic use of several antibiotics has led to the development of strains of bacteria that are resistant to medicines considered to be either Highly or Critically important to human health. Furthermore, there is evidence of the ongoing use of additional antibiotics that have been banned in both Indonesia and the United States. Overall, these conditions result in a low Criterion 4 – Chemical Use score of 4 out of 10 for extensive production of *P. monodon* and a score of 0 out of 10 for intensive *L. vannamei* production.

In extensive *P. monodon* culture, commercial feeds are largely absent since farmers rely primarily on fertilizers to induce algal blooms as a food source for farm stock. Given the absence of external feed inputs, the Final Criterion 5 – Feed score for extensive *P. monodon* farms is 10 out of 10. In intensive *L. vannamei* culture, farm stock is fed formulated, industrially-manufactured pellets, and there is industry-wide reliance on commercial feeds. Using an FCR of 1.42, and an average of 24.13% fishmeal and 3.17% fish oil in the feeds, the average Fish In: Fish Out (FIFO) ratio (based on fishmeal) is 1.52. A FIFO of 1.52 indicates that 1.52 tons of fish are required in order to supply sufficient feed to grow 1 ton of farmed shrimp. With a moderate source fishery sustainability score (-6 of -10), the final adjusted Wild Fish Use score for intensive *L. vannamei* farming is 5.28 out of 10. In addition to a 30% protein content of feed, the assumption that all protein components are edible ingredients (no inputs are byproducts or inedible crops) results in a net edible protein loss of ~60%. Furthermore, a combined ocean and land area of 10.47 ha is required to supply the amount of feed ingredients necessary to produce

1 ton of farmed shrimp. Overall, this feeding strategy results in a Criterion 5 – Feed score of 5.14 out of 10 for farmed *L. vannamei*.

There is an inherent risk of escape in pond-based shrimp aquaculture due to the exchange of pond water with the surrounding waterbody. While the vast majority of *P. monodon* farm stock are artificially cultured in hatcheries, the use of first-generation seed and the specie's native status in Indonesia indicate a low level of risk of invasive impacts to wild counterparts. *L. vannamei* are non-native to Indonesia, and despite repeated introductions and the ongoing presence of escaped *L. vannamei* in the wild, there is no evidence that they have become established. However, as a foreign shrimp species with an unestablished, yet persistent presence in the wild, *L. vannamei* escapes nonetheless present a strong likelihood for ecological disturbance from competition with other species for food and space between farmed and wild penaeids. With no direct data on recapture efforts or significant mortality levels in escaped shrimp, the overall Criterion 6 – Escape score is 5 out of 10 for farmed *P. monodon*, and 4 out of 10 for farmed *L. vannamei*.

In Indonesia, disease is one of the leading causes of mortality in farmed shrimp. *P. monodon* are known to be highly susceptible to both WSSV and YHV, and while *L. vannamei* broodstock are sourced from specific pathogen-free (SPF) hatcheries, these shrimp are not safeguarded from contracting diseases once introduced to non-SPF environments. Currently, 5 of the 8 crustacean diseases listed by the World Organization for Animal Health (OIE) have been documented in either farmed *P. monodon* or *L. vannamei*. Despite the wide use of best management practices (BMPs) throughout the industry to combat the occurrence of disease and the frequency of outbreaks, the spread of shrimp pathogens within Indonesia continues to occur with regularity due to weak regulatory structures and lax enforcement. Furthermore, communications with an industry expert indicate that there is a positive correlation between the number of neighboring shrimp farms with infected stock and the incidence of disease in wild crustaceans within the surrounding area. These conditions result in a low Criterion 7–Disease scores of 2 out of 10 for *P. monodon* and 3 out of 10 for *L. vannamei* farms in Indonesia.

In Indonesia, *P. monodon* farms are 100% reliant on fully exploited, if not overexploited, native shrimp populations due to an industry-wide dependence on wild-caught individuals for broodstock. Although ~90% of the *P. monodon* seed sold in Indonesia is produced in hatcheries, wild broodstock are required and these shrimp are not considered independent from wild stocks under Seafood Watch criteria. *L. vannamei* farms are considered to be 100% reliant on hatchery production for both broodstock and seed stock. Based on their degree of independence from wild stocks, the final score for Criterion 8 – Source of Stock is 0 out of 10 for the *P. monodon* farming industry and 10 out of 10 for the *L. vannamei* farming industry.

A variety of native wildlife species are associated with shrimp ponds in Indonesia, and many are deterred or eliminated using physical and chemical control methods. While interactions between wildlife and shrimp farms have been frequently observed, there is little recently published, peer-reviewed literature that specifically addresses mortality rates. The lack of data available for both *P. monodon* and *L. vannamei* farm-related wildlife mortalities results in a precautionary approach to scoring this criterion. Under Seafood Watch criteria, the impact of shrimp farms on low-productivity species (predatory fish, amphibians, reptiles, birds) are thus considered to be unknown, and farm-related mortalities of competitive species (polychaetes, insects, shrimps, snails, herbivorous fishes) and destructive pests (mud crabs) are not considered to be significant (regardless of differing mortality rates between *P. monodon* and *L. vannamei* farms) due to the highly productive nature and large population size of these species. As such, the same penalty score of -5 out of -10 is assessed to both extensive *P. monodon* farms and intensive *L. vannamei* farms for Exceptional Criterion 9X–Wildlife Mortalities.

In the *P. monodon* farming industry, broodstock and seed stock are generally sourced from areas other than the hatchery or farm site location. Although wild *P. monodon* broodstock may be transported some distance from domestic fishing grounds to hatcheries, and seed stock from hatcheries to growout ponds, these movements are typically local or between neighboring provinces and are not considered to represent trans-waterbody live animal shipments between ecologically distinct waterbodies. As such, no penalty score was applied to the *P. monodon* farming industry for Criterion 10X (score of 0 out of -10). For *L. vannamei* culture, although guidelines and regulatory frameworks have been established to restrict the movement of foreign shrimp, illegal international imports of *L. vannamei* broodstock and the inadequate biosecurity measures surrounding non-SPF broodstock produced by the private sector create an environment that is vulnerable to unintentionally transporting and propagating pathogens. Nonetheless, the current industry-wide lack of reliance on overseas sources (15%) and the absence of trans-waterbody movements greatly reduces the potential for the escape of unintentionally introduced species. These conditions result in a final C10X–Escape of Unintentionally Introduced Species penalty score of -1.2 out of -10 for *L. vannamei* culture.

In summary, the final numerical score for extensively farmed *P. monodon* in Indonesia is 3.12 out of 10, where the presence of 4 Red criteria (Effluent, Habitat, Disease, Source of Stock) automatically results in an overall Red “Avoid” recommendation. For intensively farmed *L. vannamei*, the final numerical score is 3.39 out of 10, where the presence of 3 Red criterion (Habitat, Chemicals, Disease) results in an overall Red “Avoid” recommendation.

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Species Overview

Two shrimp species dominate shrimp farming in Indonesia: The giant tiger prawn (*P. monodon*) and the more recently introduced, whiteleg shrimp (*L. vannamei*) (Ardjosoediro and Goetz, 2007, Yi et al. 2009, Douma and Wijk 2012, Thompson 2013). According to FAO (2005), *P. monodon* are indigenous to Indonesia with a native geographic range that includes the coasts of Australia, Asia, Southeast Asia, and Eastern Africa. Characterized by transverse bands of blue or black and yellow, adults can grow up to 33 cm (13 in) in length and attain weights ranging from 35 to 70 g. *P. monodon* are found only in tropical marine habitats, and while they spend the majority of their lives in shallow estuaries, lagoons, or mangrove areas, adults can often be found at depths of 20-50 m in offshore waters. Growing to a smaller overall size than *P. monodon*, *L. vannamei* reach a maximum length of 23 cm (9 in) and are translucent white with changes in pigmentation varying by substratum, feed composition, and water turbidity (FAO 2006). As a non-native species to Indonesia, *L. vannamei* are naturally found along the tropical Pacific Coast of Central and South America from northern Mexico to northern Peru (Briggs et al. 2004).

Shrimp farming first began in Indonesia with *P. monodon* cultured in large, extensive brackish water ponds (locally known as *tambaks*) in Java, Kalimantan, and Sulawesi (Douma and Wijks, 2012). These low-input pond systems were first adopted in eastern Indonesia (South Sulawesi) in the mid-1960s and from there spread rapidly to other areas with suitable environments (Poernomo 2004). In the late-1980s and 1990s, outbreaks of white spot syndrome virus (WSSV), yellow head virus (YHV), and monodon baculovirus (MBV) led to 50% crop failure rates for all *P. monodon* farmers at the time (Yi et al. 2009).

In response to the significant, industry-wide decreases in production, the shrimp farming industry selected *L. vannamei* as an alternative culture species based on its stronger resistance to disease, faster growth rates, lower protein requirements, and more efficient feed conversion ratios (Briggs et al. 2004, 2005; Budhiman 2005; Nurdjana 2006; Sugama 2006; Lymer et al.

2008; Afero 2009; Yi et al. 2009). Unofficially introduced to Indonesia in 1999 (Bali and East Java), *L. vannamei* received government approval in 2001 under *Ministerial Decree No. 41/2001: Release of Litopenaeus vannamei as a prime commodity* (Briggs et al. 2005, Sugama 2006, Taukhid and Nur'aini 2009, Yi et al. 2009).

Following the introduction of *L. vannamei*, the Indonesian government implemented the Revitalization of Aquaculture Program from 2005 to 2009. Within the program, directives and technical guidelines were established to support the sustainable development of shrimp farming (i.e., pond preparation, water management, feed and feeding management, chemical use, waste management, biosecurity measures, and handling and harvest management). In addition to commissioning state-run hatcheries to increase shrimp production, the Indonesian government continues to promote IndoG.A.P. certification (Indonesian Good Agricultural Practices) (Yi et al. 2009). While only a small number of farms in Indonesia are currently certified, ongoing training sessions and subsequent certification is being rapidly achieved (Anonymous 2013a).

Types of pond production systems for shrimp farming

The shrimp pond systems employed in Indonesia can be broadly divided into three basic categories: extensive, semi-intensive, and intensive farming systems (Taw 2002), and the farm area can be further differentiated where the industry is considered to be 75% extensive, 15% semi-intensive, and 10% intensive (Thompson 2013). According to Douma and Wijk (2012), *P. monodon* are the dominant species used in extensive ponds while *L. vannamei* are the primary species used in intensive ponds. Under these circumstances, extensive *P. monodon* production and intensive *L. vannamei* production are considered to be the primary farming methods for each species in Indonesia and, as such, are the two pond production systems assessed in this Seafood Watch report.

Production statistics

According to GAA's GOAL (2014), surveys of shrimp aquaculture in Asia, Indonesia is currently ranked as the third largest producer and is anticipated to remain so in 2016 (Figure 1).

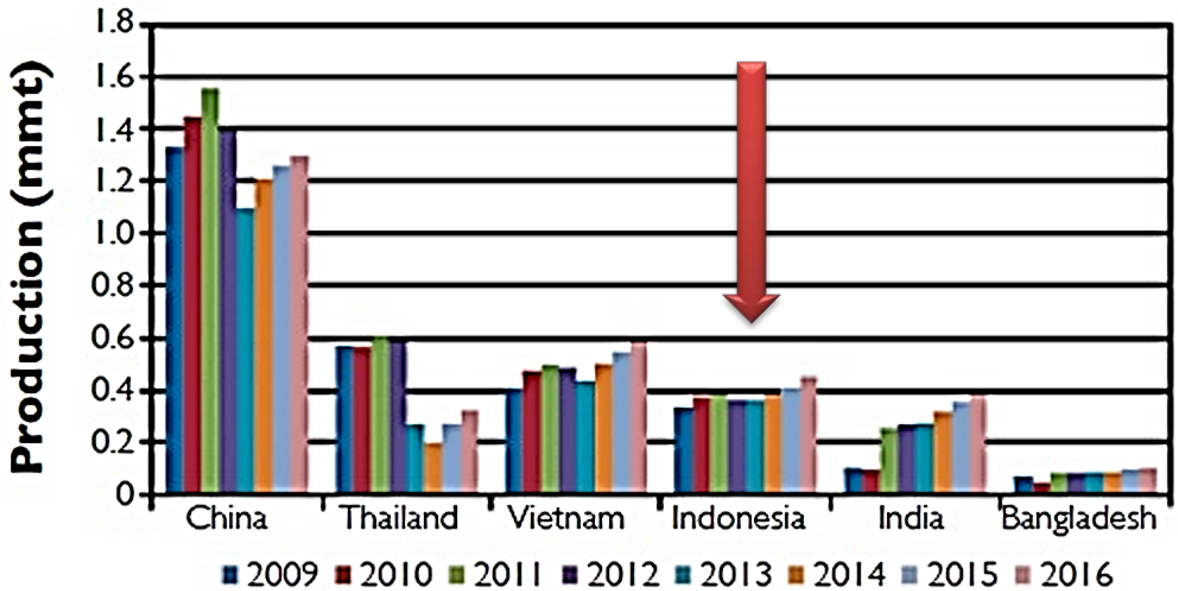

Figure 1: Annual shrimp production in Asia 2008-2015 *(Source: GAA, 2014)*

Largely due to a strong Japanese market for *P. monodon* (Ardjosoediro and Goetz 2007, Yi et al. 2009), giant tiger prawn production in Indonesia has remained relatively consistent (Figure 2) despite the introduction of *L. vannamei*. The total production of both species reached 551,507 mt in 2013.

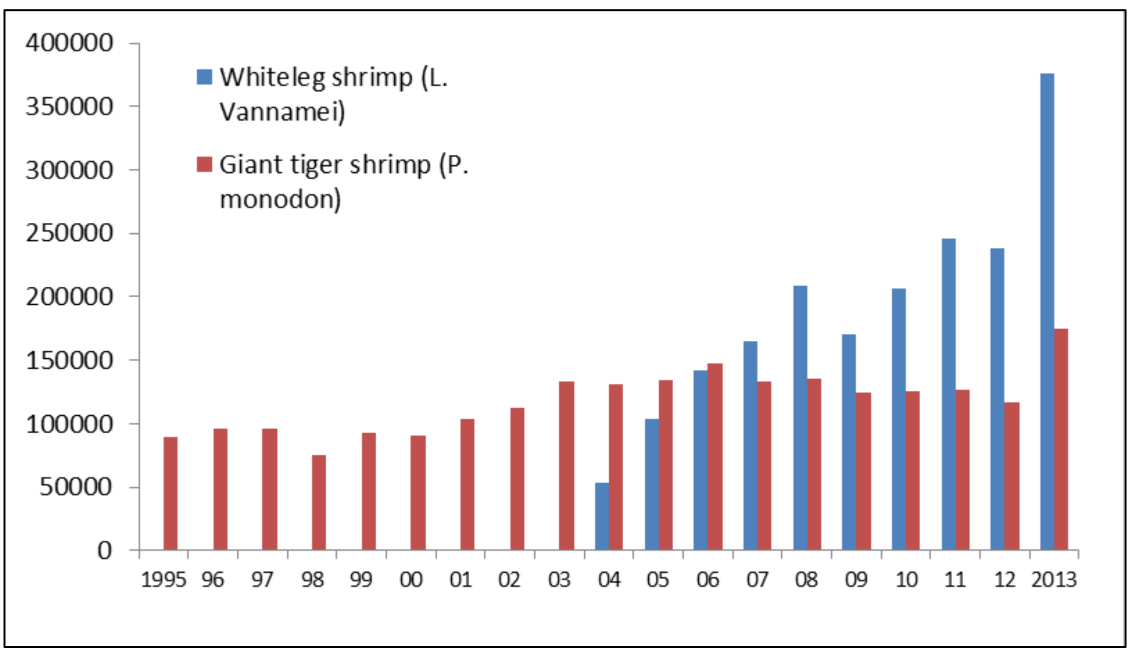

Figure 2: Annual Indonesian shrimp production (t), 1995-2013
Source: (FAO 2015)

Both shrimp species are farmed in 15 provinces across Indonesia, where the largest production centers for *P. monodon* and *L. vannamei* are in West Java and Lampung, respectively (Table 1).

Tiger Shrimp Production (Ton)			Vaname Shrimp Production (Ton)		
Provincial	2013	2014	Provincial	2013	2014
West Java	27.860	34.511	Lampung	72.051	78.985
South Sulawesi	15.319	16.036	West Nusa Tenggara	56.960	76.808
Central Sulawesi	22.403	11.890	East Java	47.150	52.951
East Java	9.842	11.036	South Sumatra	40.016	39.758
East Kalimantan	10.758	10.877	West Java	61.633	39.402
Aceh	5.621	7.241	Central Java	13.872	30.600
Southeast Sulawesi	13.275	5,120	West Kalimantan	39.092	28.972
Central Java	33.580	5,079	South Sulawesi	8.542	15.247
South Kalimantan	4.758	4.853	Southeast Sulawesi	18.369	12.802
North Sumatra	9.627	4,680	North Sumatra	19.791	10.728
South Sumatra	5.641	4.631	Gorontalo	996	6.310
West Kalimantan	1.865	2,892	Moluccas	2,065	4,000
West Sulawesi	1,898	2,462	West Sulawesi	1.138	3.915
Lampung	2.791	1,537	B a l i	2.932	3.104
North Sulawesi	390	1,487	In Yogyakarta	812	3,000

Table 1: Production volumes of farmed shrimp by province 2013-2014.
(Source: DJPB 2015)

According to the Indonesian Directorate General of Aquaculture, *P. monodon* and *L. vannamei* production have respectively risen by 3.32% and 20.49% over the last 5 years (Table 2). In 2014, an estimated 69.52% of the total annual shrimp production came from *L. vannamei*, while *P. monodon* comprised a smaller portion at 21.38%.

Indonesian Farmed Shrimp Production

	2010	2011	2012	2013	2014	Avg. Increase (%)
Black Tiger Prawn (mt)	125.519	126.157	117.888	171.583	126.595	3.32%
White-leg shrimp (mt)	206.578	246.42	251.763	390.278	411.729	20.49%
Other shrimp (mt)	48.875	28.577	46.052	77.094	53.895	14.23%
Total volume (mt)	**380.972**	**401.154**	**415.703**	**638.955**	**592.219**	**13.83%**

Table 2: Production volumes of farmed shrimp from 2010-2014. *(Source: DJPB 2015)*

Of the five shrimp species farmed in Indonesia, *P. monodon* and *L. vannamei* represent ~97.1% of national production (Table 3).

Country	Species	Scientific Name	Farm Production in 2011 (mt)	Percentage of National Production
Indonesia	Whiteleg shrimp	*Litopenaeus vannamei*	246,420	64.2%
	Giant tiger prawn	*Penaeus monodon*	126,157	32.9%
	Banana prawn	*Penaeus merguiensis*	10,757	2.8%
	Giant river prawn	*Macrobrachium rosenbergii*	617	0.2%
	Blue shrimp	*Penaeus stylirostris*	16	0.0%
Totals for Indonesia			**383,967**	**100.0%**

Table 3: Species and Production in 2011 *(Source: Thompson 2013)*

Import and export sources and statistics
In Indonesia, farmed shrimp represent the single greatest contributor to Indonesia's aquaculture export earnings (~43%) (Florina and Sukardi 2012). Of the 5 farmed shrimp varieties in Indonesia, *P. monodon* and, in particular, *L. vannamei* are the two primary species grown for the export market (DJPB 2015). Although *P. monodon* still represent a large share of the seafood export market, *L. vannamei* are clearly now the single most important shrimp aquaculture species in Indonesia (Nur 2007, DJPB 2015, FAO 2015).

The bulk of exported Indonesian shrimp is sold at markets in the United States (40%), Japan (35%), and the EU (15%, mostly France) (Douma and Wijk 2012). In 2014, the United States imported more shrimp from Indonesia (227,750 mt) (Figure 3) than any other country except India (239,564 mt) (USDA 2015). Notable Indonesian exporters to the United States market include the CP Prima Group, Mega Marine Pride Group, PT. Bahari Makmur Sejati, PT. Bancar Makmur Indah Group, and PT. Bumi Menara Internusa Group (Thompson 2013).

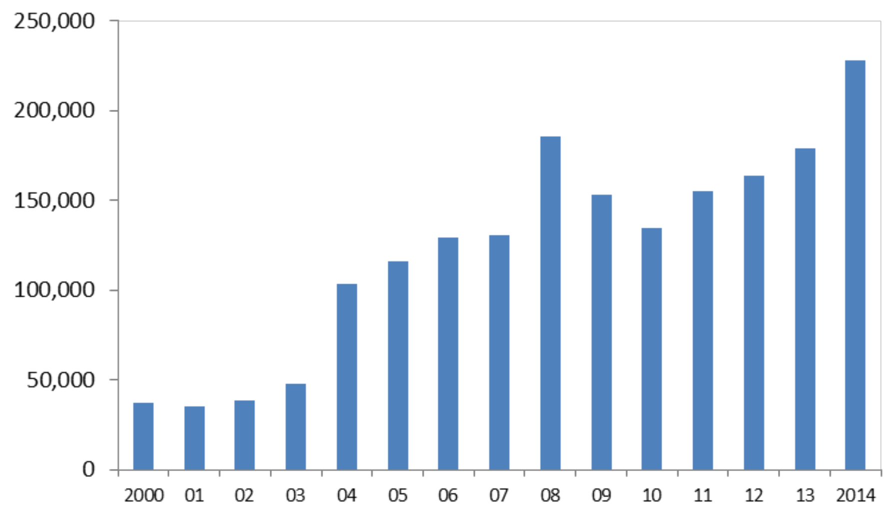

Figure 3: US shrimp imports from Indonesia (t)
Source: (USDA 2015)

While markets in the United States prefer *L. vannamei*, the Japanese market heavily favors *P. monodon*, and European markets import both *P. monodon* and *L. vannamei* equally (GAIN 2007, Ardjosoediro and Goetz 2007, Douma and Wijk 2012).

Common and Market Names

Scientific Name	*Penaeus monodon*	*Litopenaeus vannamei*
Common Name	Black tiger prawn, giant tiger prawn, tiger shrimp, or shrimp	Pacific white shrimp, white shrimp, western white shrimp, or shrimp
United States	**Giant tiger prawn** (FDA, 2015a)	**Whiteleg shrimp** (FDA, 2015b)

Indonesia	*Udang windu*	*Udang L. vannamei*
Spanish	*Langostino jumbo*	*Camarón patiblanco*
French	*Crevette géante tigrée*	*Crevette pattes blanches*
Japanese	*Ushi-ebi (うしえび)*	*Banamei-ebi (ばなめいえび)*

A Note on Nomenclature: Whiteleg shrimp was given the scientific name *Penaeus vannamei* (Boone 1931) but was changed in 1997 to *Litopenaeus vannamei* due to a commonly accepted proposal to subcategorize 6 species of the genus Penaeids (Farfante and Kensley 1997). Although a 2007 report refutes this change and encourages the use of the original name *Penaeus vannamei* (Flegel 2007), the names *Litopenaeus vannamei* and *Penaeus vannamei* are synonymous in this report.

Product forms

Shrimp from Indonesia are available in a number of product forms, including frozen or thawed, cooked or raw, head-on or head-off, tail-on or tail-off, shell-on, peeled, and deveined. They may also be present in value-added goods such as breaded shrimp or ready-made products (Ardjosoediro and Goetz 2007, Yi et al. 2009).

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 here 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 Systems

Extensive Shrimp Pond Culture

Extensive shrimp culture is characterized by irregularly shaped earthen ponds located in rural coastal areas (Yi et al. 2009). Extensive farms are typically small-scale and less than 10 hectares in size (Gräslund and Bengtsson 2001, Nurdjana 2006, Ardjosoediro and Goetz 2007, Yi et al. 2009) and are usually owner operated by local farmers that live nearby (GAIN 2007, Ardjosoediro and Goetz 2007). Under this small-holder management system, a low degree of technology, control, and financial capital are applied to ponds; farmers are typically dependent on natural waterbodies to provide water exchanges and a passive food source for shrimp (Yi et al. 2009; Florina and Sukardi, 2012; Bunting et al. 2013; pers. comm., Peet, 2015). Generally, 1-20 shrimp are stocked per square meter in a culture cycle consisting of 2 months of pond preparation followed by a 3-5 month growout period (Nurdjana 2006, Ardjosoediro and Goetz 2007, Nur 2007, Bunting et al. 2013). With an 80% survival rate, 1-3 tons of shrimp are harvested per hectare over a typical farm cycle (Briggs et al. 2004, Nurdjana, 2006). Extensive systems typically have only 2 shrimp harvests per year (Anonymous 2015a).

Extensive shrimp farms in Indonesia *(Source: Douma and Wijk 2012)*

The average life-time of a shrimp pond is estimated to be 4-7 years (IUCN et al. 2008).

Intensive Shrimp Pond Culture

In comparison to *P. monodon*, *L. vannamei* can be stocked in ponds at much greater densities because they inhabit the entire water column rather than only the pond bottom (Yi et al. 2009). As such, the introduction of *L. vannamei* to Indonesia has prompted a move toward greater stocking densities with a higher degree of system management to enhance production efficiency (Jory and Cabrera 2012). Characterized by relatively lower water exchange rates, greater biosecurity, and the use of concrete or polyethylene-lined ponds, high-density culture methods can nearly double the production capacity of standard earthen ponds (Taw 2005, Nur 2007). Typically built with dedicated intake canals with reservoir ponds, intensive shrimp farms require a high degree of water and feed management to maintain optimal water quality and minimize stress to pond stock. The investment in imported broodstock and seed, commercial feed, equipment, and electricity for intensive shrimp farming usually excludes small local farmers, where the majority of farms require their own management team with technical knowledge of chemicals, aerators, generators, and water pumps (Ardjosoediro and Goetz 2007, Yi et al. 2013).

To manage these high-tech commercial conditions, the CP Prima Group (the world's largest shrimp producer – Yi et al. 2009; pers. comm., Peet 2015) operates its shrimp farms under the nucleus-plasma model (Anonymous 2015), where a centralized company (nucleus) contracts a large number of individual shrimp farms (plasma) to supply and maintain consistent production (Nurdjana 2006, GAINS 2007).

Intensive *L. vannamei* ponds in Indonesia range from 5 to 100 hectares, but are most frequently ~10 hectares in size (Yi et al. 2009). Stocking densities are normally greater than 100 shrimp per square meter, and 3-4 month production cycles generate 10-30 mt of shrimp per hectare over a typical farming cycle (Budhiman 2005, Taw 2005, NALO 2006, Sugama 2006, Nur 2007 Yi et al. 2009, Anonymous 2015).

Intensive shrimp farms in Indonesia *(Source: Taw 2012)*

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.*

Extensive shrimp ponds, *P. monodon*

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
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	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	2.5	2.5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**25**

C1 Data Final Score	**3.13**	**RED**

Intensive shrimp ponds, *L. vannamei*

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	5	5
Feed	Yes	2.5	2.5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	10	10
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**37.5**

C1 Data Final Score	**4.17**	**YELLOW**

Literature by FAO, NACA, USAID, ACIAR, peer-reviewed journals, and communications with industry experts are particularly important data sources for a range of subjects in this assessment. Nonetheless, cumulative effluent and habitat impacts, current chemical use, associated wildlife mortalities, and the broader ecological impacts of non-native shrimp introduction have neither been well-studied nor well-documented. Furthermore, while individual ASC audits of two sites within the CP Prima Group provide some farm-level data for intensively cultured *L. vannamei*, they are not considered to reflect the industry as a whole. Farm-level data for extensive *P. monodon* farms remains poor given the absence of publicly available certification audits or any regulatory environmental monitoring requirement for small-scale, extensive farms. Overall, data accessibility and availability for extensive *P. monodon* farming and intensive *L. vannamei* farming in Indonesia is variable (depending on the subject matter) and is scored moderately or poorly based on current information availability. The final score for the Data Criterion is 3.13 out of 10 for *P. monodon* and 4.17 out of 10 for *L. vannamei*.

Justification of Ranking

While a large body of literature is available on the shrimp farming industries of Southeast Asia, information specifically on the environmental impact of shrimp farming in Indonesia is very limited (Nur 2007). As a result, older or proxy data has been used in places where current or direct information has been unavailable.

Production Statistics

For farmed *P. monodon* and *L. vannamei*, national production statistics are publicly available from the Indonesian Directorate General of Aquaculture and the Food and Agriculture Organization of the United Nations (FAO). More detailed provincial-level production data is also available from Indonesian Directorate General of Aquaculture. Further data on national shrimp production statistics were also provided to Seafood Watch in a commissioned overview of the US farmed shrimp market. While these data sources are considered to be up-to-date and cover relevant timeframes, there is an inherent level of aggregation in calculating national production statistics. As such, the data availability and quality of production statistics for the Indonesian shrimp farming industry is assessed a score of 7.5 out of 10.

Effluent

While there is evidence in the literature indicating that large portion of the nutrients in the waterbodies surrounding shrimp farms are generated from commercial feeds and fertilizers, direct information on the resulting environmental impact from the industry is largely unavailable and a risk-based assessment was performed for *P. monodon* and *L. vannamei*. For unfed *P. monodon* culture, fertilizer application rates and production yields were identified through personal communication with an industry expert, and fertilizer-nitrogen percentages were available from FAO. Pond discharge information is based primarily on recent studies in Java (2012) and Kalimantan (2013). Although pond sludge is "dried, collected, and discarded away from the farm area," (Taw 2005) the impact of the disposed waste on the surrounding environment is currently unknown. Furthermore, the majority of the information available on the content of effluent regulations and the enforcement of management measures is either dated (up to 9 years old) or non-specific to Indonesia (i.e., White et al. 2013). Although personal communication with industry experts were used to support identification of applicable regulatory contents, no data was obtained on the effectiveness of enforcement measures (monitoring requirements). As such, the data availability and quality for effluent impact and management for farmed *P. monodon* receives a data score of 2.5 out of 10.

For *L. vannamei* culture (which utilizes commercial feed), pond discharge characteristics and waste production calculations are generated from feed company data, peer-reviewed literature, publicly available presentations on shrimp farming, ASC certification audits, and personal communications with industry experts. As with *P. monodon*, the data of several of these sources are very dated (up to 14 years old) or are non-specific to Indonesia. Furthermore, no data could be found on the effectiveness of enforcement measures (monitoring requirements). As such, the data availability and quality for effluent impact and management for farmed *L. vannamei* also receives a score of 2.5 out of 10.

Habitat

For habitat conversion by both *P. monodon* and *L. vannamei* farms, scoring relies on data published by the Indonesian Ministry of Forestry, peer-reviewed literature, and reports which describes the impact of shrimp farming on Indonesia's coastal mangrove forests. Industry expansion trends were available from peer-reviewed literature, an FAO report, or provided by an industry expert. To assess farm siting management and regulatory enforcement, this report relies primarily on literature from NACA, USAID, and FAO with some support from ASC certification audits and communications with industry experts. As in the Effluent Criterion, the data of several of these sources are dated (up to 10 years old) or are non-specific to Indonesia, and provide a low level of confidence concerning the industry's impacts and regulatory enforcement measures. As such, the data availability and quality for habitat impact and management for both *P. monodon* and *L. vannamei* is assessed a score of 2.5 out of 10.

Chemical Use

Data on chemical use in Indonesian shrimp farming is primarily based on peer-reviewed literature from Taslihan and Sunaryanto (1990), Supriyadi and Rukyani (2000), and Gräslund and Bengtsson, (2001). While it is believed to be low, the application rate of chemicals in extensive farming of *P. monodon* is currently unknown. For intensive *L. vannamei* farming, antibiotic use is the driving factor in the chemical use score, and is supported by reports from a number of different authors, including Gräslund and Bengtsson (2001), Tendencia and De la Pena (2001), Holmström et al. (2003), Le et al. (2005), Huys et al. (2007), and Banerjee et al. (2012). Evidence of the development of clinical resistance to chloramphenicol (an antibiotic highly important to human health) is supported by Angka (1997). While a large portion of the antibiotic use data in this report is sourced from dated information, there is up-to-date evidence from the FDA of the ongoing use of illegal antibiotic residues in Indonesian shrimp imported into the U.S. Overall, while chemical use information is scarce for extensive monodon farming, antibiotic residue bans by the U.S. provide a high level of confidence that the chemical impacts of the current *L. vannamei* farming industry are assessed with accuracy. Overall, the Chemical Use data score is 2.5 out of 10 and 5 out of 10 for *P. monodon* and *L. vannamei*, respectively.

Feed

For extensive *P. monodon* culture, commercial feeds are largely absent from the production cycles. This data is supported by peer-reviewed literature and several published reports by FAO, USAID, the ACIAR, and a working paper by the Maastricht School of Management. Without external feed inputs, the Feed Criterion is not applicable to extensive *P. monodon* farms and scoring is omitted from the Data Criterion. For *L. vannamei*, specific feed data is primarily sourced from two feed companies (ASC audits), communications with industry experts, and both grey and peer-reviewed literature (up to 10 years old) by FAO, the NACA, and publicly available presentations on shrimp farming. However, data on percentages of fishmeal and fish oil from byproducts, fishmeal and fish oil yield, the percentage of protein from nonedible sources (in terms of edibility to humans), and the proportion of nonedible crop and land animal ingredients in shrimp feeds are absent. Furthermore, Indonesian feed mills are very secretive regarding the variety of fisheries that supply their fishmeal and fish oil and many sources are currently unknown. Given the minimal information on specific feed components and the unknown nature of fishmeal sourcing produces a low level of confidence in the data being assessed, and results in a Feed data score for farmed *L. vannamei* of 2.5 out of 10.

Escapes and Animal Movements

The escape risk posed by both *P. monodon* and *L. vannamei* farms is described in peer-reviewed literature and published reports (up to 11 years old) by FAO, publicly available presentations on shrimp farming, and also by two ASC audit reports. Most of these data sources, however, are non-specific to Indonesia. Moreover, there is no direct data on recapture or mortality of escapees for Indonesia's shrimp farming industry. In terms of invasiveness, *P. monodon* escapes are assessed primarily using a report by FAO in 2005 and by comparisons to shrimp farms in Thailand (Benzie 2000). For *L. vannamei*, invasiveness is based largely on literature that indicates an unestablished but persistent presence of these shrimp in the wild in Thailand. (Score combined with Animal Movements)

This factor assesses the availability of data regarding live animal movements between ecologically distinct waterbodies and between countries. Data on the international movement of farmed *P. monodon* are described in published reports by USAID and ACIAR. For *L. vannamei*, data on the industry's reliance on international movement of farm stock are described in regional trade publications and local news articles. The reliance on trans-waterbody movements of both species are currently unknown. Disease management measures are found in BMP manuals that are described by the NACA. Furthermore, evidence of illegal importation of *L. vannamei* are provided by FAO reports, and the subsequent introduction of non-native diseases are described in peer-reviewed literature. Data on the transboundary movement of non-SPF *L. vannamei* broodstock are described in a World Aquaculture Society presentation, an FAO report, and in peer-reviewed literature.

Given the absence of direct data on the impacts of escaped shrimp in Indonesia, and the outdated or unverified nature of the data for animal movements, *P. monodon* and *L. vannamei* have a final Escapes and Animal Movement score of 2.5 out of 10.

Disease

While there is ample literature on the major diseases affecting farmed shrimp in Indonesia, the Disease Criterion score for both species is based primarily on evidence of disease transmission between farmed shrimp and native, wild populations (Overstreet et al. 1997, Joint Subcommittee on Aquaculture (JSA) 1997), and communications with one industry expert that indicated a positive correlation between the number of neighboring shrimp farms with infected stock and the incidence of disease in wild crustaceans within the surrounding area. As such, the three major data sources for the disease impacts of the shrimp farming industry are not sufficient to give robust confidence that the impacts of disease on wild species are well understood in Indonesia. These data limitations produce a score of 2.5 out of 10 for both *P. monodon* and *L. vannamei*.

Source of Stock

This factor assesses an aquaculture industry's reliance on wild capture for broodstock and farm stock. Data on the source of farmed *P. monodon* in Indonesia and stock assessments of wild *P. monodon* populations in Southeast Asia are described in peer-reviewed literature as well as FAO and USAID reports. Currently, there is no information available on population-level impacts from sourcing wild *P. monodon* for shrimp farming. Data on the source of farmed *L. vannamei* are also sourced primarily from published literature by FAO, SEAFDEC, USAID, USDA, the ACIAR, and a presentation by Blue Aqua International. While the majority of these data sources for both shrimp species are between five and ten years old, two recent ASC audit reports and communications with industry experts indicate that all *L. vannamei* broodstock continue to be sourced from hatcheries. As such, *P. monodon* and *L. vannamei* farming in Indonesia are given respective Source of Stock data scores of 2.5 out of 10 and 10 out of 10.

Predators and Wildlife Interactions

While interactions between a variety of wildlife species and shrimp ponds have been documented in Indonesia (Taslihan and Sunaryanto 1990), there is no recently published, peer-reviewed literature that specifically addresses the population-level impact of shrimp farms on affected wildlife species. Information on current wildlife management measures were described in peer-reviewed literature as well as FAO reports and by communications with industry experts. As such, both *P. monodon* and *L. vannamei* farming in Indonesia are given a Predator and Wildlife Interaction data score of 2.5 out of 10.

Data Criterion — Conclusions and Final Score

Data accessibility and availability for extensive *P. monodon* farming and intensive *L. vannamei* farming in Indonesia is variable depending on the subject matter and current information availability. The final score for the Data Criterion is 3.13 out of 10 for *P. monodon* and 4.17 out of 10 for *L. vannamei*.

Criterion 2: Effluents

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.*

Extensive shrimp ponds, *P. monodon*

Effluent Risk-Based Assessment

Effluent Parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N ton-1)	68.17		
F2.1b Waste discharged from farm (%)	51		
F2 .1 Waste discharge score (0-10)		6	
F2.2a Content of regulations (0-5)	0.5		
F2.2b Enforcement of regulations (0-5)	0.25		
F2.2 Regulatory or management effectiveness score (0-10)		0.05	
C2 Effluent Final Score		**3.00**	**RED**
Critical?	NO		

Intensive shrimp ponds, *L. vannamei*

Effluent Risk-Based Assessment

Effluent Parameters	Value	Score	
F2.1a Biological waste (nitrogen) production per of fish (kg N ton-1)	39.68		
F2.1b Waste discharged from farm (%)	51		
F2 .1 Waste discharge score (0-10)		7	
F2.2a Content of regulations (0-5)	1		
F2.2b Enforcement of regulations (0-5)	0.25		
F2.2 Regulatory or management effectiveness score (0-10)		0.1	
C2 Effluent Final Score		**4.00**	**YELLOW**
Critical?	NO		

The Seafood Watch Effluent Criterion combines the total amount of waste released per ton of production with an assessment of applicable management measures and their implementation to provide a measure of the impact from discharged wastes. For extensive *P. monodon* farms, the total waste discharged (using nitrogen as a proxy) is estimated to be 68.17 kg N t^{-1}, and 39.68 kg N t^{-1} for intensive *L. vannamei* farms. Although the effluent discharged from shrimp farms is collected between farming cycles, the fate of sludge material disposed of offsite is currently unknown. Regarding regulatory management, consideration of the cumulative impacts from multiple farms is absent for *P. monodon* farms and is poorly addressed in the *L. vannamei* farming industry. There is no provision for public review of EIA documents and very little transparency in the EIA process for large farm sites over 50 ha in size. While farm clusters, which collectively form a combined 50 ha, are still subject to environmental assessment, the enactment of this legislation is not a legal requirement and smaller, non-fed farming operations (at least 75% of the Indonesian shrimp farming industry) are exempt from the EIA process. Furthermore, decentralized policy-setting practices in Indonesia have resulted in an ineffective environmental regulatory regime characterized by weak institutional support at local levels of government and inadequate enforcement. Overall, pond systems in Indonesia produce moderate impacts to the environment from effluent discharge. When combined with poor management of cumulative impacts, these conditions result in a final Criterion 2 – Effluent score of 3 out of 10 for extensively farmed *P. monodon* and 4 out of 10 for intensively farmed *L. vannamei*.

Justification of Ranking

The brackish water in shrimp ponds contains high levels of nutrients and organic matter, especially toward the end of the production cycle (World Bank et. al. 2002, Nur 2007). These nutrients are derived mainly from metabolic products and uneaten food, as well as from the addition of fertilizer use during pond preparation to stimulate plankton blooms (World Bank et. al. 2002, Anonymous 2015a). Discharge of pond waters containing high levels of nutrients and organic matter into the surrounding environment can have negative impacts at the local, regional or cumulative scale.

While evidence in the literature indicates that a high proportion of the nutrients in waterways adjacent to shrimp farms originate from the application of commercial feeds and fertilizers (Nur 2007), information specifically on the resulting environmental impact of shrimp farms in Indonesia remains very limited. Given the poor data availability for effluent-based environmental impacts, the risk-based assessment method (as opposed to evidence-based) is employed in this Seafood Watch report for both extensively farmed *P. monodon* and intensively farmed *L. vannamei*.

Factor 2.1a – Biological Waste Production Per Ton of Shrimp

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. Studies by Briggs and Funge-Smith (1994) and Green et al. (1997) indicate 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 waste found in the water column or as settle-solids promotes eutrophication in the pond system as well as in neighboring waters upon their release from the farm system (Davis et al. 2006).

Waste Production from Extensive *P. monodon* Culture

For Factor 2.1a, the nitrogenous waste produced per ton of shrimp is used as a proxy-indicator to measure the amount of waste discharged during a typical shrimp production cycle. The data required to calculate this quantity includes the protein content of feed, FCR, fertilizer-based nitrogen inputs, and the protein content of whole harvested shrimp (i.e., protein is 16% nitrogen).

In the absence of any feed inputs, *P. monodon* farmed in extensive ponds consume phytoplankton and zooplankton suspended in the pond water, and fertilizers are widely used to promote algal blooms (Tacon 2002, Nur 2007, Ardjosoediro and Goetz 2007, Martin 2008, Yi et al. 2009, Douma and Wijk 2012, Bunting et al. 2013, Anonymous 2013, Anonymous 2015a). While both organic and inorganic fertilizers were commonly used in the past (Supriyadi and Rukyani 2000), transport and labor costs have made organic fertilizers (i.e., manures) more expensive to use than alternative inorganic options (Nur 2007). Due to the weak financial status of many extensive shrimp farming households, inorganic urea and phosphate fertilizers (i.e., triple super phosphate) are most commonly used today to stimulate phytoplankton growth (Supriyadi and Rukyani 2000, Nur 2007, Florina and Sukardi 2012, Bunting et al. 2013, Anonymous 2013a). As such, effluent wastes are still generated due to fertilizer inputs, and these effluents are discharged to the surrounding waterbody through daily water exchanges and during pond drainage at harvest.

Based on surveys of shrimp farming households in Central Java and South Sulawesi province, a total fertilizer input of 212.547kg per ton of shrimp was calculated using a fertilizer application rate of 14.67kg ha^{-1} and a *P. monodon* production yield of 69.02kg ha^{-1} (Anonymous, 2013b). Calculations for the nitrogen component of total fertilizer inputs are based on FAO's specifications for the two most commonly used fertilizers, inorganic urea (46% N) and triple super phosphate (0% N) (FAO, 2015c). Despite the fact that triple super phosphate has no nitrogen content, its discharge from ponds can still contribute to effluent impacts. With no information describing the inclusion rates of urea and triple super phosphate, it is assumed that all fertilizers are 46% nitrogen. It is therefore calculated that fertilizer-based nitrogen inputs are 97.77 kg per ton of shrimp produced. Based on research by Boyd (2007) the protein content of a whole, harvested, farmed shrimp is considered to be 18.5%.

Overall, 68.17 kg of nitrogen-based waste are produced per ton of *P. monodon*. As described above, this value has been adjusted to include fertilizer inputs that contain no nitrogen. As a result, the calculated percentage of nitrogen inputs that are lost to the environment increase from 55% to 70%.

Waste Production from Intensive *L. vannamei* Culture

Intensive shrimp farming has developed rapidly on a global scale, but faces a number of issues related to discharged waste, including water intake and outputs to the same waterbody (self-pollution), cumulative pollution between farms in the region, as well as impacts to the coastal environment (White et al. 2013).

The protein content of shrimp feeds can range as high as 53% (pers. comm., Feed company “a,” 2014), but an averaged protein component of 30% is typical of current feeds (Briggs et al. 2005, Sugama 2006, Afero 2009, Anonymous 2013, Anonymous 2013a). Recently reported feed conversion ratios (FCRs) for intensively farmed *L. vannamei* vary from 1.1 to 1.73 (Sugama 2006, Afero 2009, Shishehchian 2011, Taw 2012, Bussarin and Unger 2015a, Bussarin and Unger 2015, pers. comm. Peet 2015, Anonymous 2015). Based on these data sources, an average FCR value of 1.42 is used in this assessment and is considered to be representative of the intensive *L. vannamei* farming industry in Indonesia. Fertilizers are rarely used in intensive farming because there is little need to fertilize ponds if the shrimp are fed commercial feeds (Gräslund and Bengtsson 2001, Yi et al. 2009, Jory and Cabrera 2012) and communications with industry experts concur that this is the case for intensive *L. vannamei* farms (Anonymous 2013a). Based on research by Boyd (2007) the protein content of whole, harvested, farmed shrimp is considered to be 17.8%.

Based on these values, a calculated 39.68 kg of nitrogen-based waste are produced per ton of *L. vannamei*. This amount of waste indicates that ~58% of the nitrogen inputs into intensive *L. vannamei* farms are lost.

Factor 2.1b – Production System Discharge
A large proportion of the nutrients generated by farmed shrimp are suspended solids (World Bank et al., 2002), and their collection, treatment, or otherwise appropriate disposal can mitigate environmental impacts during water exchanges or pond drainage.

Extensive *P. monodon* Farms
In Asia, shrimp farming practices vary somewhat from region to region depending on the local conditions and financial status of individual farmers. Although the exact water exchange practices employed in the Indonesian shrimp farming industry are challenging to define, extensive pond systems are by definition dependent on tidal exchange with very limited use of mechanical pumping (Bunting et al. 2013), and are characterized by a water exchange rate that is typically <5% per day due to the absence of mechanical pumps (Tacon et al. 2002, 2004, Jory and Cabrera 2012). These water exchange practices are consistent with studies directly observing extensive farms in Indonesia (Florina and Sukardi 2012, Bunting et al. 2013).

Intensive *L. vannamei* Farms
In general, the introduction of *L. vannamei* into Indonesian aquaculture has prompted a move toward intensive culture systems with limited water exchange (Briggs et al. 2004, 2005, Taw 2005, Nur 2007, Florina and Sukardi 2012). While farm management strategies with higher stocking rates may exchange as much as 40% of the pond volume on a daily basis (especially toward harvest) (Tacon et al. 2004), more standard daily exchange rates range from 5%–25% (Jory and Cabrera 2012), and two auditing reports by ASC for the CP Prima Group (Indonesia’s largest shrimp producer) indicate a daily exchange rate typically between 3.5% and 5.8% (Bussarin and Unger 2015a, Bussarin and Unger 2015).

Effluent Treatment
Data from the literature and also from certification audits provide evidence that most shrimp farms in Indonesia do not treat pond water before discharging it into the surrounding waterbody:

In Java, shrimp ponds have been modified to include reservoirs for inputs, but typically do not have effluent treatment facilities (Taw 2005, Florina and Sukardi 2012). In Bali and elsewhere, newly established shrimp farms use seawater directly and discharge effluents back into the ocean; similar practices exist in the southern part of West Java (Taw 2005). Furthermore, two intensive *L. vannamei* farms (operated by the CP Prima Group) discharge effluent from harvested ponds directly into outlet canals without treatment (Bussarin and Unger 2015, Bussarin and Unger 2015a).

Sludge Disposal
According to Merican (2015), almost 90% of farms in Indonesia have installed some type of equipment or system to remove pond sludge. In the shrimp farming industry, accumulated particulate waste is either "dried, collected, and discarded away from the farm area" (Taw 2005, Nur 2007), or used to reinforce pond dikes and embankments (ADB et al. 2007, Bussarin and Unger 2015, 2015a, pers. comm. Peet 2015). While solid waste retained at the farm site reduces the overall discharge of sludge material produced by shrimp farms, whether the waste that is removed from the farm is discarded in an environmentally responsible manner is currently unknown.

Under Seafood Watch criteria, the quantity of effluent-based waste that is discharged by a production system is established using a basic score that can be adjusted by production and management techniques that reduce the discharge of nutrients. The basic, unadjusted production system waste discharge score for ponds with daily water exchange is 0.51 (approximately 51% of the waste generated leaves the production system as effluent). While effluent treatment and settling ponds are rarely used in Indonesian shrimp farms (Taw 2005, Florina and Sukardi 2012, Pers. comm. Peet 2015), sludge disposal practices are regularly applied between farming cycles. However, the proportion of Indonesian shrimp farmers which retain pond sludge at the farm site as pond-building material and the environmental impact of off-farm discards are both currently unknown. Without robust evidence, no production system discharge adjustment was applied to Factor 2.1b, and 51% of the waste produced in both *P. monodon* and *L. vannamei* ponds is considered to be discharged from the farm.

Combining the scores from 2.1a and 2.1b produces a final Factor 2.1 score of 6 out of 10 for *P. monodon* and 7 out of 10 *L. vannamei*.

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. While the following regulations are not species-specific with regard to shrimp aquaculture, and are thus

equally applicable to *P. monodon* and *L. vannamei*, effluent management between extensive and intensive shrimp farms differ due to the nature of the production systems.

Effluent Legislation and Discharge Limits

At the national level, the Fisheries Act #31 (2004)—the principal legislative tool for aquaculture management—provides a broad definition and guidelines for sustainable aquaculture, and especially for shrimp farming (NALO 2006, Phillips et al. 2009). Relevant effluent guidelines include parameters for water management, pond preparation, feeding management, chemical and drug restrictions, and particulate/dissolved waste management (Sukadi, 2008). According to Phillips et al. (2009), general information is scarce regarding the environmental quality standards that have been established for Indonesian shrimp farms and criteria for local water quality parameters may be different from national standards. While Government Regulation #19 (1999) and Government Regulation #5 (2014) regulate effluent discharges into marine waters, they contain no specific standard for aquaculture effluents (NALO, 2006; Anonymous, 2015a). Furthermore, although marine carrying capacity models have been developed in Indonesia, they are only appropriate for cage farming of marine fish (Halide et al. 2008). Under these laws, effluent legislation is considered to be only moderately applicable to *L. vannamei* farming practices and inapplicable to extensive *P. monodon* farming (no EIA requirement – see 3.2a Environmental Impact Assessment).

Effluent Monitoring

The presence of effluent monitoring measures for all stages of the shrimp production cycle (i.e., peak biomass, harvest, etc.) cannot be verified. As such, scoring reflects a low level of confidence in the matter.

Site-specific Effluent Management

Under Presidential Decree #10 (2000), the Environmental Impact Management Agency is tasked with coordinating and implementing the EIA process for aquaculture (Phillips et al. 2009). Although effluent limits are included in EIA requirements, effluent discharges are not held to site-specific limits in the shrimp farming industry (Anonymous 2015, Anonymous 2015a).

Cumulative Impacts

Although the water quality impacts associated with an individual shrimp farm are typically limited because of their small size, the simultaneous operation of a large number of these farms can produce cumulative impacts at the regional scale (White et al. 2013).

Several factors significantly reduce the effective management of cumulative impacts in Indonesia's shrimp farming industry, including a 50 ha minimum farm-size requirement for EIA evaluations (Government Regulation No. 54 (2002)) and a lack of any environmental assessment requirement for extensive (i.e., non-fed) shrimp farms (Sukadi 2008, Florina and Sukardi 2012, Anonymous 2013). Although Article No. 46 of Ministry of Marine and Fisheries Decree No. 02/MEN/2004 stipulates that smaller shrimp farms which collectively form a combined 50 ha are still subject to environmental assessment, the enactment of this legislation is not a legal requirement and authorization falls to district or city governments. Overall, regulatory management of cumulative effluent impacts are absent for *P. monodon* farms and are only regulated to a minor degree in Indonesia's *L. vannamei* farming industry.

For Factor 2.2a, these regulatory conditions result in a score of 0.5 out of 5 for *P. monodon* and 1 out of 5 for *L. vannamei*.

Factor 2.2b – Enforcement of Effluent Regulations and Management Measures
Management of environmental resources in Indonesia has been strongly influenced by a policy of decentralization, where management responsibilities have been delegated to provincial, district, and municipal governments (Phillips et al. 2009). Under this regulatory management system, relevant environmental agencies and enforcement organizations for shrimp farming are numerous and difficult to identify.

Pursuant to Presidential Decree #23 (1982) and Law #22 (1999), local governments are held responsible for identifying coastal areas for aquaculture development, and for the management, use, and conservation of marine resources in their own territorial waters (NALO 2006, Ardjosoediro and Goetz 2007). This process has had significant implications for the practical management of aquaculture impacts, where the lack of capacity, skills, and regulatory knowledge present in local administrative systems has resulted in localized departures from national standards (Anonymous 2013) and limited enforcement of EIA procedures and monitoring requirements (Phillips et al. 2009). Under the decentralized policy-setting in Indonesia, the implementation and enforcement of existing effluent management regulations is considered to be both ineffective and inappropriate for the scale of the industry.

In addition to the decentralization of authority, communications with an industry expert (Anonymous 2015) indicate that there are no robust penalties for infringements or active enforcement of effluent regulations for all stages of the shrimp production cycle.

Overall, these regulatory enforcement conditions result in a final Factor 2.2b score of 0.25 out of 5 for both *P. monodon*, and *L. vannamei*.

Combining Factor 2.2a and 2.2b results in an overall regulatory enforcement and management effectiveness score of 0.05 out of 10 for *P. monodon*, and a score of 0.1 out of 10 for *L. vannamei*.

Effluent Criterion—Conclusions and Final Score
The total nitrogen waste produced per ton of production is ~68.17 kg for farmed *P. monodon*, and ~39.68 kg for *L. vannamei*.

Approximately 51% of the waste from both extensive *monodon* and intensive *L. vannamei* production systems (i.e., 34.77 kg N and 20.24 kg N, respectively) leaves the farm boundary. These quantities of discharged waste result in Factor 2.1 scores of 6 out of 10 for farmed *P. monodon* and 7 out of 10 *L. vannamei*.

Although national legislation has been established to address discharged aquaculture wastes, the bulk of farming operations continue to be exempt from the EIA process and the decentralized policy-setting in Indonesia has resulted in an ineffective environmental regulatory regime characterized by weak institutional support and inadequate enforcement. Furthermore, the lack of regulation for extensive (unfed) or small-scale farms, and the absence of any regional impact assessment requirement indicates that there is poor management of cumulative impacts in Indonesia's shrimp farming industry. These conditions indicate a low level of environmental protection in the sector and results in a regulatory content and enforcement (Factor 2.2) score of 0.05 out of 10 for *P. monodon*, and a score of 0.1 out of 10 for *L. vannamei*

Combining the overall waste discharge score with the overall management effectiveness score results in moderate effluent scores of 3 out of 10 for *P. monodon* and 4 out of 10 for *L. vannamei*, and reflects uncertainties with respect to potential cumulative impacts from a poorly regulated aquaculture industry.

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.*

Extensive shrimp ponds, *P. monodon*

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		4.00	
F3.2a Content of habitat regulations	2.00		
F3.2b Enforcement of habitat regulations	0.75		
F3.2 Regulatory or management effectiveness score		0.60	
C3 Habitat Final Score		**2.87**	**RED**
Critical?	NO		

Intensive shrimp ponds, *L. vannamei*

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		4.00	
F3.2a Content of habitat regulations	2.50		
F3.2b Enforcement of habitat regulations	1.00		
F3.2 Regulatory or management effectiveness score		1.00	
C3 Habitat Final Score		**3.00**	**RED**
Critical?	NO		

In Indonesia, shrimp aquaculture has historically been responsible for ~50% of the depletion in Indonesia's coastal mangrove forests (~750,000 ha). Although the shrimp farming industry currently represents the single largest historic cause of mangrove loss in Indonesia, very few new shrimp farms are being built in mangrove areas, as prospective *L. vannamei* farmers typically upgrade sites that were originally intended for *P. monodon* culture. Regarding habitat and farm siting management, inadequate EIA requirements and poor spatial planning laws have resulted in a regulatory framework that is unable to effectively manage or mitigate cumulative impacts. Nonetheless, ongoing habitat restoration efforts by various regional and international programs have resulted in the rehabilitation of 1,973 ha of mangroves per year. Combining the degree of habitat conversion with management effectiveness results in a Habitat Criterion score of 2.87 out of 10 for extensive *P. monodon* farms and a score of 3 out of 10 for intensive *L. vannamei* farms.

Justification of Ranking

F3.1 Habitat Conversion and Function

Globally, the country of Indonesia has the highest concentration of mangroves, both in terms of area and in the number of mangrove species (Ilman et al. 2011). Intact mangrove ecosystems are critical habitats that provide numerous ecological services and contain high biological, hydrological, and ecological value. Mangroves are specifically cited for their ability to protect coastlines from both storm surges and erosion by currents and waves, shelter aquatic organisms from heat and predators, and provide nursery, spawning, and feeding areas for a wide variety of marine species (Primavera, 1997, Sukardjo 2009, Powell and Osbeck 2010).

Although the conversion of coastal mangrove forests into shrimp ponds began in 1970, the prohibition of the Indonesian trawl net fisheries in 1980, together with ensuing government policies to stimulate shrimp aquaculture (Ilman et al. 2011), resulted in a large changeover by commercial fishermen to shrimp aquaculture and a drastic increase in mangrove deforestation (Ilman et al. 2011, Bosma et al. 2012). In subsequent years, the conversion of mangrove forests reached a peak from 1998 to 2005 when approximately 300,000 ha of mangroves were cleared in East Kalimantan alone (Ilman et al. 2009).

According to Ilman et al. (2011), data published by the Ministry of Forestry (2005) indicates that the shrimp farming industry is responsible for the removal of 750,000 ha of mangrove forests. By applying a moderate estimate of the overall reduction in Indonesia's mangrove cover (1.5 million ha) (Ilman et al. 2011), the findings suggest that shrimp aquaculture has been solely responsible for 50% of the depletion in mangroves and constitutes the single greatest cause of mangrove loss in Indonesia. The bulk of the mangrove deforestation is attributed to the *P. monodon* farming industry (Anonymous 2015), which was the primary culture species ~30 years prior to the introduction of *L. vannamei* in 2001. Currently, *P. monodon* farming still comprises at least 75% of the total number of shrimp farms in Indonesia and is responsible for the majority of the shrimp farming area in Indonesia (Douma and Wijk 2012, Thompson 2013, Anonymous 2015).

Historic Trends in Industry Expansion

In practice, most shrimp farm sites are chosen on the basis of availability rather than suitability (World Bank et al. 2002). While current estimates of the total pond area in Indonesia range from 400,000 to 612,000 ha (IUCN et al. 2008, Ilman et al. 2011, Bosma et al. 2012), almost no new shrimp farms are being built because it is now illegal to build shrimp farms in tidal and mangrove areas (Illman et al. 2011, Jory and Cabrera 2012). Although there has been some expansion of the *L. vannamei* industry into new farming areas, the majority of *L. vannamei* farms have been constructed on sites that were originally cleared for *P. monodon* production (i.e., farmers upgrade from extensive production to intensive production) (Briggs et al. 2005). Whether for *P. monodon* or *L. vannamei*, these shrimp farm sites are typically between 10 and 20 years in age (Merican 2007). Furthermore, an industry expert observes that the current growth trend is one of intensifying production on existing farms or switching from other aquaculture species (i.e., milkfish, tilapia) to shrimp rather than converting new habitat

(Anonymous, 2013b). As a whole, habitat conversion by the shrimp farming industry is considered to be minor relative to historic conversion levels and, as such, few significant new impacts on coastal habitats are currently taking place.

For Factor 3.1, these habitat conversion conditions result in a score of 4 out of 10 for both *P. monodon* and *L. vannamei*.

Factor 3.2a Habitat and Farm Siting Management Effectiveness
In this factor, the ability of management systems to regulate ecological impacts from habitat conversion for shrimp farms is assessed. While the following regulations are not species-specific with regard to shrimp aquaculture, and are thus equally applicable to *P. monodon* and *L. vannamei*, habitat and farm siting management between extensive and intensive shrimp farms differ due to the nature of the production systems.

At the national level, the Ministry of Forestry manages marine protected areas throughout Indonesia (Phillips et al. 2009). Relevant legislation, including Presidential Decree #32 (1990) and Ministerial Decree 28 (2004), require the adoption of a coastal greenbelt (Width = 130 x average difference between highest and lowest tides in a year) and require shrimp farmers (operating in former mangrove areas) replant trees in locations not actively used in production (Phillips et al. 2009).

In addition to national legislation, numerous regional and national level programs and initiatives now target the restoration and re-habilitation of mangroves in (Martin 2008, Sukadi et al. 2006, Powell and Osbeck 2010). These efforts have resulted in an estimated mangrove rehabilitation rate of 1,973 ha per year (Illman et al. 2011). Importantly, however, the full recovery of mangrove forest may take as long as ~20 years (Primavera and Esteban 2008), and there is no guarantee that a sufficient area can be recovered to fulfill the ecosystem functions which existed prior to the introduction of shrimp aquaculture.

Site Selection
In the Indonesian shrimp farming industry, Law #26 (2007) provides for the establishment of protected areas in Indonesia's coastal waters. Although the law establishes zones based on various environmental categories (including mangroves), its relatively late adoption in 2007 has produced spatial planning criteria that disregards many of the licenses previously granted for aquaculture (White et al. 2013). As such, it has been widely accepted that the overdue and inadequate requirements in spatial planning laws have resulted in the loss of coastal mangrove forests (Phillips et al. 2009). Although a framework for environmental planning at a regional level is absent, increasingly, site selection is being considered through the licensing system, voluntary codes of conduct, and in environmental certifications (Phillips et al. 2009).

In terms of regulatory control for cumulative impacts, as noted in the Effluent Criterion, regulations to manage the environmental impacts derived from multiple farm sites are absent in Indonesia. While a review of the literature provides detailed information for EIA assessments of individual aquaculture developments, there is no evidence that indicates a framework for addressing cumulative impacts from aquaculture is established in Indonesia.

Environmental Impact Assessment

In Indonesia, the Environmental Management Act #23 (1997) mandates the application of the EIA process for any activity or development with potentially significant impact on the environment (Phillips et al. 2009). Under the Decree of the State Minister of the Environmental Affairs #3 (2000) and the Ministry of Environmental Decree #308 (2005), aquaculture is defined under "fisheries" as being subject to the EIA process, requiring an applicant to develop "an environmental impact study, an environmental management plan, and an environmental monitoring plan" (Phillips et al. 2009).

Under Government Regulation #27 (1999), an EIA is a mandatory part of licensing procedures for new shrimp farms larger than 50 ha in size (Phillips et al. 2009). The licenses to conduct aquaculture in brackish waters are issued by either provincial or district authorities, depending on the location of the farm. To enforce EIA requirements, shrimp farms are sampled randomly by the Environmental Impact Management Agency over the duration of each license period (Anonymous 2013).

For shrimp farming in Asia, EIA requirements focus primarily on high value, intensive operations (White et al. 2013). While "most legislation is oriented towards farms that cover larger areas that have a high potential for environmental impact" (White et al. 2013), small-scale aquaculture systems are subject to less EIA regulation. Notably, although the EIA process in Indonesia has been widely applied to large-scale shrimp farms (Phillips et al. 2009), small-scale farmers are exempt from this requirement under Government Regulation No. 54 (2002). Specifically, an EIA is only required for shrimp farms (for either *P. monodon* or *L. vannamei*) exceeding 50 ha in size. Given that at least 75% of the total number of shrimp farms in Indonesia are extensive (Douma & Wijk 2012, Thompson 2013), small-scale, extensive systems that are typically <10 hectares in size (Gräslund and Bengtsson 2001, Nurdjana 2006, Ardjosoediro and Goetz 2007, Yi et al. 2009), the majority of the shrimp farming industry is not subject to the EIA process. In addition to this exemption, the EIA process is applied only to new aquaculture developments, and not to existing farm sites that are expanding in size (Phillips et al. 2009). Under these conditions, only a very small number of large *L. vannamei* farms are required to implement the EIA process in Indonesia.

For Factor 3.2a, these regulatory conditions result in a score of 2 out of 5 for *P. monodon*, and 2.5 out of 5 for *L. vannamei*.

Factor 3.2b Regulatory Effectiveness and Enforcement

Under Presidential Decree #23 (1982) and Law #22 (1999), Indonesia's management of environmental resources is delegated to provincial, district, and municipal governments (Phillips et al. 2009), where local authorities are tasked with identifying coastal areas for aquaculture development (NALO 2006, Ardjosoediro and Goetz 2007). This delegation of authority has had significant impact on the consistent and practical management of aquaculture impacts, where the lack of capacity, skills, and regulatory knowledge present in local administrative systems has resulted in localized departures from national standards (Anonymous 2013) and limited enforcement of EIA procedures and monitoring requirements (Phillips et al. 2009).

As a result of the decentralized policy-setting in Indonesia's environmental management regime, not only are relevant environmental agencies and enforcement organizations for shrimp farming numerous and difficult to identify, they are also considered to be ineffective and inappropriate for the scale of the industry. In Southern Java, for example, hundreds of illegal shrimp farms continued to operate for at least another year following warnings by regulators before being closed in January 2015 (Jakarta Post 2015). With a history of weak law enforcement in Indonesia's environmental management regime (Ilman et al. 2011), few management limits or restrictions for habitat impacts are expected to be achieved within Indonesia's aquaculture industry.

In terms of regulatory control for cumulative impacts, Indonesia lacks a standard framework that addresses cumulative impacts from aquaculture. While Article No. 46 of Ministry of Marine and Fisheries Decree No. 02/MEN/2004 stipulates that smaller shrimp farms that collectively encompass 50 ha are subject to environmental assessment, this legislation is not a legal requirement unless individual district or city governments choose to enforce it.

Public Access, Participation, and Transparency in the EIA Process

The EIA process in Indonesia has no provision for public review aside from including NGO representatives on review committees on behalf of the local community (Phillip et al. 2009). EIA reports and their findings are generally not disseminated to local communities or relevant stakeholders (ADB 2005, Phillips et al. 2009, Bussarin and Unger 2015, Bussarin and Unger 2015a). Furthermore, no effective feedback mechanism exists at any aquaculture management level (national, provincial, or district) (Phillips et al. 2009). Under these conditions, transparency in the EIA process is considered low.

Overall, for Factor 3.2b, these regulatory enforcement conditions result in a score of 0.75 out of 5 for *P. monodon* and 1 out of 5 for *L. vannamei*.

Combining Factor 3.2a and 3.2b results in an overall regulatory enforcement and management effectiveness score of 0.6 out of 10 for *P. monodon*, and a score of 1 out of 10 for *L. vannamei*.

Habitat Criterion—Conclusions and Final Score

Shrimp aquaculture in Indonesia has been responsible for the removal of ~50% (~750,000 ha) of Indonesia's coastal mangrove forests. These coastal ecosystems are considered to be high-value habitats under Seafood Watch criteria. However, although the shrimp farming industry represents the single largest cause of mangrove loss in Indonesia, almost no new shrimp farms are being built as *L. vannamei* production typically upgrades farm sites originally intended for *P. monodon* culture. While the majority of habitat conversion in Indonesia is considered historic, the recovery of mangrove ecosystems can take 20 years or more. Under these conditions, farmed *P. monodon* and *L. vannamei* both receive a moderate-low habitat conversion score of 4 out of 10.

Regarding habitat and farm siting management, the policy to decentralize authority for implementing aquaculture regulations has resulted in weak enforcement capabilities at both national and local levels of government. Both the lack of EIA requirements for small-scale shrimp farms and poor spatial planning laws have further resulted in regulatory regimes that are ineffective at managing or mitigating cumulative impacts. Nonetheless, some progress has been made through the institution of coastal greenbelts and ongoing habitat restoration efforts by various regional and national programs. These overall conditions result in a regulatory content and enforcement score of 0.6 out of 10 for *P. monodon*, and a score of 1 out of 10 for *L. vannamei*.

Combining the overall Habitat Conversion score with the overall Management Effectiveness score results in a Red Habitat Criterion score of 2.87 out of 10 for extensive *P. monodon* farms and a low-moderate score of 3 out of 10 for intensive *L. vannamei* farms. This reflects the widespread destruction of coastal mangrove forests and the ongoing institutional and enforcement problems in the management system regulating Indonesia's shrimp farming industry.

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.*

Extensive shrimp ponds, *P. monodon*

Chemical Use parameters	Score	
C4 Chemical Use Score	**4.00**	
C4 Chemical Use Final Score	**4.00**	**YELLOW**
Critical?	NO	

Intensive shrimp ponds, *L. vannamei*

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

Shrimp farmers in Indonesia have relied on a wide variety of synthetic and natural chemicals and biological treatments to prevent and treat disease, to enhance the health status of the cultured species, and to improve pond conditions. While extensive *P. monodon* farmers typically do not apply medications and antibiotics during the production cycle, the use of pesticides, such as saponin and diazinon, impacts non-target species in and around the farm site. For intensive *L. vannamei* culture, the widespread, prophylactic use of several antibiotics has led to the development of strains of bacteria that are resistant to medicines considered to be either highly or critically important to human health. Furthermore, there is evidence of the ongoing use of additional antibiotics that have been banned in both Indonesia and the United States. Overall, these conditions result in a low Criterion 4 – Chemical Use score of 4 out of 10 for extensive production of *P. monodon* and a score of 0 out of 10 for intensive *L. vannamei* production.

Justification of Ranking

Over the past 15-20 years, the Asian aquaculture sector has been overwhelmed by several aquatic animal health problems throughout the region (Ardjosoediro and Goetz 2007). Consequently, farmers have relied on a wide variety of synthetic and natural chemicals and biological treatments to prevent and treat disease outbreaks, to enhance the health status of the culture species, and to improve the environmental conditions of the production system (Rico et al. 2012).

In Indonesian shrimp ponds, the most common chemical products applied are fertilizers and liming material (Gräslund and Bengtsson 2001). Disinfectants, antibiotics, pesticides, and probiotics are also used to improve production (Table 4).

Table 4: Chemicals used in Indonesian shrimp farming

Chemical Types	Administration	Dose	Primary Use	Reference
Antibiotics				
Oxytetracycline (Tetracycline)	Oral (in feed)	50mg/kg/d, 7-10d	Antibiotic	Taslihan and Sunaryanto 1990 Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001 Ardjosoediro and Goetz 2007 Sapkota et al. 2008
	Bath (hatchery)	5-10ppm	Antibiotic	Supriyadi and Rukyani 2000 Sapkota et al. 2008
Chloramphenicol	Immersion (hatchery)	5ppm	Antibiotic	Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001 Sapkota et al. 2008
Erythromycin (Macrolides)	Bath (hatchery)	1-4ppm	Antibiotic	Taslihan and Sunaryanto 1990 Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001 Sapkota et al. 2008
Streptomycin (Aminoglycosides)	Long bath (hatchery)	4ppm	Antibiotic	Supriyadi and Rukyani 2000 Sapkota et al. 2008
Prefuran (Nitrofurans)	Immersion (in feed and in hatchery)	1ppm	Antibiotic	Supriyadi and Rukyani 2000 Sapkota et al. 2008 FDA 2015d
Neomycin (Aminoglycosides)	Bath (hatchery)	4ppm	Antibiotic	Supriyadi and Rukyani 2000 Sapkota et al. 2008
Oxolinic acid (Quinolone)	No data	No data	Antibiotic	Gräslund and Bengtsson 2001 Sapkota et al. 2008
Enrofloxacin (Quinolone)	Oral (in feed)	No data	Antibiotic	FDA 2015e
Ampicillin	No data	No data	Antibiotic	Teo et al. 2000, 2002
Pesticides				
Formalin	Immersion	25ppm	Protozoan/crustacean parasites, fungicide	Taslihan and Sunaryanto 1990 Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001 Ardjosoediro and Goetz 2007 Jory and Cabrera 2012
Malachite green oxalate	Immersion	0.15ppm	Fungicide (Mycosis in hatcheries)	Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001
Potassium permanganate	Immersion	4-40ppm	General disinfectant (ponds and hatcheries)	Taslihan and Sunaryanto 1990 Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001

Methylene blue	Immersion	1-2ppm	Protozoan infections and fungicide	Supriyadi and Rukyani 2000
Saponin (Tea seed cake)	Long bath Spreading	7-12ppm, or 100kg ha^{-1} y^{-1}	Piscicide,	Taslihan and Sunaryanto 1990 Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001 ADB et al. 2007 Nur 2007 Ardjosoediro and Goetz 2007 Bunting et al. 2013
Diazinon	Spreading	0.1 ppm	Insecticide (mysids)	Taslihan and Sunaryanto 1990 Gräslund and Bengtsson 2001
Dichlorvos	No data	No data	Insecticide	Anonymous 2015
Disinfectants				
Chlorine (calcium/sodium hypochlorite)	Immersion	60ppm	General disinfectant (ponds and hatcheries)	Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001 Taw 2010 Rico et al. 2012 Jory and Cabrera 2012
Soil conditioners				
Lime (calcium carbonate, calcium hydroxide, calcium oxide)	Spreading	100-8000 kg/ha (soil) 10-500 kg/ha (water)	Soil conditioner; ph regulation	Supriyadi and Rukyani 2000 Gräslund and Bengtsson 2001 Ardjosoediro and Goetz 2007 Nur 2007 Rico et al. 2012

Chemical Use in Extensive *P. monodon* Farms

In pond preparation, empty ponds are regularly treated with pesticides (fungicides, insecticides, and piscicides) and disinfectants before stocking to eradicate predators and competitors, and dosed with lime to counteract pond water and sediment acidification (Table 4) (Nur 2007, Supriyadi and Rukyani 2000, Bunting et al. 2013, Anonymous 2015). Although medication and antibiotics are not normally employed in small-scale operations for economic reasons (Ardjosoediro and Goetz 2007, pers comm. Peet 2015), antibiotic residues in imported Indonesian shrimp have been nonetheless detected in large quantities in the U.S. (Oktaviani and Erwidodo 2005, Ardjosoediro and Goetz 2007) and import bans do not distinguish between *P. monodon* and *L. vannamei* (FDA 2015d, 2015e).

Furthermore, while inorganic water/soil conditioners (i.e., liming compounds) are not expected to have toxic effects on aquatic organisms (Anderson 1992, Boyd & Massaut 1999, Sakai 1999), pesticides, disinfectants, and antibiotics have been demonstrated to be toxic to aquatic organisms (Jones et al. 2002, Emmanuel et al. 2004, Maltby et al. 2009, Zounkova et al. 2011). Examples of pesticide impacts include mass fish-kills in mangrove areas adjacent to shrimp ponds treated with saponin (tea seed cake) (Primavera 1993) and symptoms of acute toxicity in non-target crustaceans from contact with organophosphate pesticides (e.g., diazinon) (GESAMP 1997, Leight and Van Dolah 1999).

While frequency of use of chemicals is believed to be low in extensive farming of *P. monodon* in Indonesia, it remains an unknown, and pond systems discharge water to the natural environment without relevant treatment. These prevailing farming characteristics warrant a moderate level of concern for potential chemical impacts and result in an overall Criterion 4 – Chemical Use score of 4 of 10 for farmed *P. monodon*.

Chemical Use in Intensive *L. vannamei* Farms

In Indonesia, aquaculture systems have been characterized by a developing trend toward intensive culture. As a result of this intensification, an increase in disease outbreaks has occurred and various therapeutants (i.e., antibiotics and other chemicals) have been widely used for treatment and prevention of infectious diseases in intensive *L. vannamei* farms (Supriyadi and Rukyani 2000). Broad-spectrum disinfectants are also used in intensive growout ponds to clean equipment and sometimes to treat disease (GESAMP 1997).

Antibiotic Use in Intensive *L. vannamei* Farms

In the *L. vannamei* farming industry, the use of antibiotics has been very common in both hatcheries and at the farm site. Commercial shrimp feeds are regularly enriched with antibiotics for use in growout ponds (Flaherty et al. 2000, Supriyadi and Rukyani 2000).

A major concern with the use of antibiotics is the development of resistant strains of bacteria, which can compromise treatment effectiveness (Rico et al. 2012). In a global survey regarding antimicrobial resistance in aquaculture (25 countries), shrimp was the species where respondents most often reported resistance across all antimicrobials (Tuševljak et al. 2013). Studies (Gräslund and Bengtsson (2001), Tendencia and De la Pena (2001), Holmström et al. (2003), Le et al. (2005), Huys et al. (2007), and Banerjee et al. (2012)) have shown the presence of antibiotic-resistant bacteria in Southeast Asian shrimp farms regularly using antibiotics. In Indonesia, elevated levels of bacterial antibiotic resistance in and around aquaculture production systems has been documented for chloramphenicol, erythromycin, oxolinic acid, and oxytetracycline as far back as 1997 (Angka 1997, Sapkota et al. 2008). The use of antibiotics in intensive Indonesian shrimp farms and their persistence in sediments alter the ecological structure of microbial communities in surrounding waterbodies and lead to the proliferation of antibiotic-resistant bacteria in the wild (Kautsky et al. 2000, Gräslund and Bengtsson 2001, Rico and Van den Brink 2014). Furthermore, these antibiotics are all considered either Highly or Critically important to human health (WHO 2011).

Throughout Southeast Asia, there is no clear distinction between applications for different groups of substances (i.e., chlorine can be used as both a disinfectant and an herbicide) and a farmer might also use a product differently than intended by the producer (Gräslund and Bengtsson 2001). Insufficient knowledge of disease diagnoses, chemical efficacy under tropical aquaculture conditions, and the mode of action of these chemical compounds, particularly among small-holders, is a major concern (Pathak et al. 2000; Holmström et al. 2003, Faruk et al. 2005), and the misuse of chemicals by extensive *P. monodon* farmers is known to occur (especially with pesticides) (Anonymous 2015). Furthermore, several studies have shown that in many rural areas, aquaculture farmers are heavily influenced by extensive promotional programs carried out by chemical retailers (Tonguthai, 2000; Faruk et al., 2008), contributing to the inappropriate use of chemicals (e.g., excessive prophylactic use of antibiotics). These conditions and farming practices are considered to be representative of Indonesia's *P. monodon* farming industry in this Seafood Watch assessment.

In Indonesia, national chemical regulations for aquaculture are ambiguous, where Act #31 (2004) does not directly list banned substances, but instead prohibits the use of any chemicals that may "threaten aquatic resources" (Article 8(1)) (NALO 2006). While the Decree of the Minister of Agriculture #466 (1999) establishes a certification system for agricultural drug use, no specific provisions are made regarding their use in aquaculture (NALO 2006). At the farm level, guidance on restricted chemicals is communicated through BMP manuals (Sukadi 2008).

In recent years, there has been an increasing demand for stricter health requirements for Indonesian shrimp, and chemical quality standards have been imposed on imports of farmed shrimp by the U.S., the EU, and Japan (Ardjosoediro and Goetz 2007). Although chloramphenicol, malachite green, and nitrofurans have been banned in either the U.S. or Indonesia (malachite green, nitrofurans, fluoroquinolones, and chloramphenicol in the U.S. and all chemicals considered to "threaten aquatic resources" in Indonesia) (GESAMP 1997, Supriyadi and Rukyani 2000, Oktaviani and Erwidodo 2005, Rangkuti 2007, Ardjosoediro and Goetz 2007), residual concentrations of these illegal compounds have been detected in imported shrimp from Asia (Vass et al. 2008). Oxytetracycline, chlortetracycline, and chloramphenicol (in particular) have been detected in large quantities (Oktaviani and Erwidodo 2005, Ardjosoediro and Goetz2007), and the presence of antibiotic residues has resulted in regular rejection of shipments of Indonesian farmed shrimp by U.S., EU, and Japanese markets (Supriyadi and Rukyani 2000, Serrano 2005, Ardjosoediro and Goetz 2007, IUCN et al. 2008, Rico et al. 2012). Despite the Indonesian government establishing national chemical regulations for aquaculture in 2004 and a monitoring program specifically for antibiotic use (especially chloramphenicol) in shrimp farms (Sukadi 2008), the United States FDA has continued to institute import bans for additional antibiotic residues (nitrofurans and the fluoroquinolone enrofloxacin) in shrimp shipments from Indonesia as recently as October 2015 (FDA 2015d, 2015e). These import bans indicate that the use of illegal antibiotics is ongoing in Indonesia's shrimp farming industry regardless of regulatory controls.

Chemical Criterion—Conclusions and Final Score

In Asia, a wide variety of synthetic and natural chemicals and biological compounds are used to treat diseases, enhance the health status of the culture species, or improve the environmental conditions in shrimp aquaculture.

In Indonesia, chemical use is variable depending on the capital strength of the farmer. Although medications and antibiotics are normally not employed in extensive *P. monodon* ponds due to the absence of a way to administer treatment (commercial feeds), the discharge of pesticides and disinfectants in *P. monodon* farms has resulted in impacts to non-target species. In intensive *L. vannamei* farming, the widespread and prophylactic use of antibiotics has resulted in the development of bacterial strains that are resistant to antibiotics. Furthermore, a large number of the pesticides, disinfectants, and antibiotics used throughout the industry are known to be toxic to non-target aquatic organisms present in the surrounding environment. Due to the lack of knowledge on responsible chemical use, banned antibiotics such as nitrofuran and enrofloxacin (the latter recognized as Critically important to human health by the World Health Organization) continue to be detected in some shipments of shrimp originating from Indonesia.

Overall, these conditions result in a low Criterion 4 – Chemical Use score of 4 out of 10 for extensive *P. monodon* farms and a score of 0 out of 10 for intensive *L. vannamei* farms.

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 nonedible portion of farmed fish.*

Extensive shrimp ponds, *P. monodon*

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

Intensive shrimp ponds, *L. vannamei*

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	1.52	6.19	
F5.1b Source fishery sustainability score		-6.00	
F5.1: Wild Fish Use		5.28	
F5.2a Protein IN	36.93		
F5.2b Protein OUT	14.86		
F5.2: Net Protein Gain or Loss (%)	-59.76	4	
F5.3: Feed Footprint (hectares)	10.47	6	
C5 Feed Final Score		**5.14**	**YELLOW**
Critical?	NO		

In extensive *P. monodon* culture, commercial feeds are largely absent since farmers rely primarily on fertilizers to induce algal blooms as a food source for farm stock. Given the absence of external feed inputs, the Final Criterion 5 – Feed score for extensive *P. monodon* farms is 10 out of 10. In intensive *L. vannamei* culture, farm stock is fed formulated, industrially-manufactured pellets, and there is industry-wide reliance on commercial feeds. Using an FCR of 1.42, and an average of 24.13% fishmeal and 3.17% fish oil in the feeds, the average Fish In: Fish Out ratio (based on fishmeal) is 1.52. A FIFO of 1.52 indicates that 1.52 tons of fish are required in order to supply sufficient feed to grow 1 ton of farmed shrimp. With a moderate source fishery sustainability score (-6 of -10), the final adjusted Wild Fish Use score for intensive *L. vannamei* farming is 5.28 out of 10. In addition to a 30% protein content of feed, the assumption that all protein components are edible ingredients (no inputs are byproducts or inedible crops) results in a net edible protein loss of ~60%. Furthermore, a combined ocean and land area of 10.47 ha is required to supply the amount of feed ingredients necessary to produce one ton of farmed shrimp. Overall, this feeding strategy results in a Criterion 5 – Feed score of 5.14 out of 10 for farmed *L. vannamei*.

Justification of Ranking

In Indonesia, shrimp are farmed under a wide range of different pond systems and are fed using an equally diverse array of different foods and feeding strategies throughout the production cycle (Jory et al. 2001, Tacon 2002, Cuzon et al. 2004, Tacon et al. 2004).

Feeding Practices for *P. monodon*

In extensive *P. monodon* farming, the availability and cost of organic and inorganic fertilizers can constrain the advancement of small-holder farms (Nur 2007). Although extensive *P. monodon* farmers in Aceh (northern Indonesia) are known to apply feeds during the last 30 days of a 3-month culture period (pers. comm., Peet 2015), the ability to supplement production with feed is strongly limited by the financial status of small-scale farmers and the high cost of commercial pellets (Tacon et al. 2004, Florina and Sukardi 2012, Bunting et al. 2013, pers. comm. Peet 2015). Under these circumstances, only 20% of the *P. monodon* production in Indonesia utilized feed in 2007 (Nur 2007); a decrease of 30%–40% since 2002 (Tacon 2002).

Although it is challenging to verify these industry trends in a country with a range of feeding practices for each pond system, sufficient confidence can be gained from the scientific literature and communications with industry experts, which indicate that feeds are now largely absent throughout current extensive *P. monodon* production cycles, that supplementary feeds are used sparingly and toward the tail-end of production, and that this is the normal situation for extensive farming systems in Indonesia (Tacon 2002, Ardjosoediro and Goetz 2007, Nur 2007, Martin 2008, Yi et al. 2009, Douma and Wijk 2012, Bunting et al. 2013, Anonymous 2013). Additionally, extensive shrimp farms are by definition low input systems that typically do not use feeds (Tacon et al. 2004, Jory and Cabrera 2012, White et al. 2013).

Therefore, the absence of external feed inputs is considered to be characteristic of the majority of extensive *P. monodon* production systems in Indonesia, where at least 80%, if not more, of the *P. monodon* farming industry apply only fertilizers to supplement production. As such, the Criterion 5 – Feed score is 10 out of 10 for the extensive *P. monodon* farming industry.

Feeding Practices for *L. vannamei*

In Indonesia, aquaculture systems have been characterized by a developing trend toward intensive culture and there has been a growing need for commercial feeds (Nur 2007). Under current intensive production methods, *L. vannamei* farmers rely completely on formulated, commercially-manufactured pellets as the sole source of shrimp feed (Tacon 2002, Nur 2007, Widanarni et al. 2010).

Typically fed 6-8 times a day, hand feeding is commonly practiced by walking along the pond dike, while floating mechanical devices are used to distribute feed in the middle of the pond (Nur 2007, Jory and Cabrera 2012). The feeding rate is ~50% of the shrimp biomass at the beginning of the production cycle (Adiwidjaya et al. 2004), however feeding trays are subsequently used to monitor feeding response every 10 to 30 days (Nur 2007, Jory and Cabrera 2012).

Factor 5.1. Wild Fish Use

This factor combines an estimate of the amount of wild fish used to produce farmed *L. vannamei* with the sustainability of the fisheries from which they are sourced (Table 5).

Data values	Feed company "A" Bussarin and Unger, 2015 Boyd, 2007 Nur, 2007
Average fishmeal inclusion level	24.13%
Percentage of fishmeal from byproducts	Not specified (0% used in calculation)
Fishmeal yield (from wild fish)	Not specified (22.55% used in calculation)
Average fish oil inclusion level	3.17%
Percentage of fish oil from byproducts	Not specified (0% used in calculation)
Fish oil yield (from wild fish)	Not specified (5% used in calculation)
Feed Conversion ratio (FCR)	1.42
Calculated values	
Fish In : Fish Out ratio for fishmeal	1.52
Fish In : Fish Out ratio for fish oil	0.9
Seafood Watch FIFO score (0-10)	**6.19**

Table 5: Wildfish Use data and calculated values

In the Feed Criterion, the FCR is used in calculations to determine the industry's reliance on wild feed-fish, the net protein gain/loss in shrimp production, and the combined ocean/land area appropriated for feed ingredients. The FCR in farmed *L. vannamei* varies from region to region and is dependent on the duration of the farming period, feed composition, and each farmer's individual feeding strategy (Tacon 2002). Over a farming season, feed conversion ratios typically range from 1.1 to 1.73 using commercially available pellet feeds (Briggs et al. 2004, Sugama 2006, Afero 2009, Shishehchian 2011, Taw 2012, Bussarin and Unger 2015, Bussarin and Unger 2015a, Pers. comm. Peet 2015, Anonymous 2015). As such, an average FCR of 1.42 is considered representative of the industry in this Seafood Watch assessment.

With approximately 24.13% fishmeal and 3.17% fish oil in the feeds, the average Fish In: Fish Out ratio is 1.52. A FIFO of 1.52 indicates that 1.52 tons of fish are required to supply sufficient feed (fishmeal in particular) to grow 1 ton of farmed shrimp. These feed characteristics result in a moderate FIFO factor score of 6.19 out of 10.

Source Fishery Sustainability

According to an industry expert, Indonesian feed mills are very secretive regarding the variety of fisheries that supply their fishmeal and fish oil (Anonymous 2015). Although Peruvian anchovy and local sardine have been identified as sources of fishmeal for shrimp feeds (Anonymous 2015, Bussarin and Unger 2015, 2015a), other fisheries that provide fishmeal and fish oil to Indonesia are currently unknown. A precautionary score of -6 out of -10 is applied for unknown source fisheries and subsequent unknown sustainability of those stocks. This reduces the FIFO score by -0.91 and generates a final Wild Fish Use score of 5.28 out of 10, indicating a moderate conservation concern regarding wild fish use in *L. vannamei* feeds.

Factor 5.2. Net Protein Gain or Loss

In Factor 5.2, a net protein value is quantified by calculating protein inputs and outputs in a typical shrimp farming cycle. Using the available literature and data from two feed companies, the protein contribution from feed was calculated using an average protein content of 30% and an average FCR of 1.42. Without specific information, it is assumed from the data provided that 100% of the feed protein from both marine and crop ingredients are edible (in regards to human consumption), and that no protein is sourced from fisheries byproducts, terrestrial animals, or crop byproduct ingredients. As such, 53.5% of the feed protein is considered to be from edible marine sources (i.e., fishmeal from whole fish) and the remaining 46.5% of feed protein is considered to be from edible crop sources (e.g., soybean meal). The protein generated by shrimp farming is calculated using a protein content of 17.8% in a whole, harvested farmed shrimp, and an edible yield of 67% for *L. vannamei*. It is assumed that 50% of the inedible byproducts from harvested *L. vannamei* are used in other food production processes. Overall, these feed ingredients produce a calculated 59.8% loss in edible protein, and result in a low-moderate factor score of 4 out of 10 (Table 6).

Data values	Range	Final value	Reference
Protein content of feed	20-53%	30%	Feed company "a" Anonymous, 2013 Anonymous, 2013a Bussarin and Unger, 2015 Bussarin and Unger, 2015a Afero, 2009 Nur, 2007 Sugama, 2006 Briggs et al., 2005
Percentage of total protein form non-edible sources (by-products, etc.)	-	(0% used in calculations)	Unknown
Percentage of protein from edible sources	-	100%	Feed company "a" Bussarin and Unger, 2015 Bussarin and Unger, 2015a
Percentage of protein from edible crop sources	-	46.50%	-
Feed conversion ratio (FCR)	1.1-1.73	1.42	Anonymous, 2015 Pers. comm., Peet, 2015 Bussarin and Unger, 2015 Bussarin and Unger, 2015a Taw, 2012 Shishehchian, 2011 Afero, 2009 Sugama, 2006 Briggs et al., 2004
Protein content of whole harvested shrimp	-	17.8	Boyd, 2007
Percentage of farmed shrimp by-products utilized	-	(50% used in Calculations)	Unknown
Calculated values			
Protein INPUT per ton of farmed shrimp		36.9%	
Protein OUTPUT per ton of farmed shrimp		14.9%	
Net protein loss		-59.8%	
Seafood Watch protein score (0-10)		**4**	

Table 6: Net protein data and calculated values

Factor 5.3. Feed Footprint

This factor is an approximate measure of the global area required to produce feed ingredients. By considering the marine, terrestrial crop, and terrestrial land animal ingredients, this factor provides an estimate of the ocean area and land area required to produce the ingredients necessary for the production of feed required per ton of farmed shrimp. Without specific data, it is assumed that all non-marine ingredients are edible crop (i.e., for human consumption) and that no inedible land animal byproducts are utilized as ingredients. As such, 27.3% of the feed is sourced from marine ingredients and the remainder (72.7%) is composed of edible crops. For *L. vannamei*, 10.08 ha of ocean area and 0.39 ha of land area are required to supply the amount of feed ingredients necessary to produce one ton of farmed shrimp. These conditions result in a moderate Factor 5.3 score of 6 out of 10 (Table 7).

Parameter	Feed company "A" Bussarin and Unger, 2015 Boyd, 2007 Nur, 2007
Marine ingredient inclusion in feed	27.3%
Crop ingredients inclusion in feed	72.7%
Land animal ingredient inclusion in feed	0%
Ocean area used per ton of farmed shrimp	10.08ha
Land area	0.39ha
Total area	10.47ha
Seafood Watch Footprint score (0-10)	**6**

Table 7: Feed footprint data and calculated values

Feed Criterion—Conclusions and Final Score

For extensive *P. monodon* production systems, the absence of external feed inputs results in a final Criterion 5 – Feed score of 10 out of 10.

In intensive *L. vannamei* culture, there is an industry-wide reliance on commercial feeds, where a FIFO of 1.52 indicates that 1.52 tons of fishmeal are required in order to supply sufficient feed to grow 1 ton of farmed shrimp. The consequence of this process is a net protein deficit, where 59.8% of protein inputs are not utilized. The inefficiency of shrimp feeds for *L. vannamei* is further compounded by the 10.47 ha/ton production of ocean and land area appropriated for feed ingredients. Overall, the extractive nature of intensive farmed *L. vannamei* results in a final C5 – Feed Criterion score of 5.14 out of 10.

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.*

Extensive shrimp ponds, *P. monodon*

Escape Parameters	Value	Score	
F6.1 Escape Risk		2.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		8	
C6 Escape Final Score		**5.00**	**YELLOW**
Critical?	NO		

Intensive shrimp ponds, *L. vannamei*

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

There is an inherent risk of escape in pond-based shrimp aquaculture due to the exchange of pond water with the surrounding waterbody. While the vast majority of *P. monodon* farm stock are artificially cultured in hatcheries, the use of first-generation seed and the specie's native status in Indonesia indicate a low level of risk of invasive impacts to wild counterparts. *L. vannamei* are non-native to Indonesia, and despite repeated introductions and the ongoing presence of escaped *L. vannamei* in the wild, there is no evidence that they have become established. However, as a foreign shrimp species with an unestablished, yet persistent presence in the wild, *L. vannamei* escapes nonetheless present a strong likelihood for ecological disturbance from competition with other species for food and space between farmed and wild penaeids. With no direct data on recapture efforts or significant mortality levels in escaped shrimp, the overall Criterion 6 – Escape score is 5 out of 10 for farmed *P. monodon*, and 4 out of 10 for farmed *L. vannamei*.

Justification of Ranking

F6.1a. Escape Risk

There is an inherent risk of escape in pond-based shrimp aquaculture due to the nature of the production system. The escape of farmed shrimp into the surrounding environment has been documented in Indonesia and can be expected as a result of water exchanges, accidental release during harvesting, release from hatcheries and during transport, as well as mass escape during flooding events and levee breaches (Briggs et al. 2004, 2005; Sugama 2006; Boyd 2008). In general, farms for both *P. monodon* and *L. vannamei* are located in low-lying areas along the Indonesian coast (Boyd 2008, Yi et al. 2009, Florina and Sukardi 2012, Bunting et al. 2013). Importantly, "The height of tsunamis in Indonesia suggests that any shrimp farm constructed in coastal areas could be damaged by the average tsunami regardless of construction method," (Boyd 2008). In terms of regulatory management, there are currently no monitoring requirements for shrimp escapes in Indonesia and legislation is limited to government advice (Anonymous 2015a).

Extensive *P. monodon* Farms

In Asia, shrimp farming practices vary somewhat from region to region depending on local conditions and the financial status of individual farmers. Although the exact water exchange practices employed in the Indonesian shrimp farming industry are challenging to define, extensive pond systems by definition are dependent on tidal exchange with limited use of mechanical pumping (Bunting et al. 2013), and are characterized by a water exchange rate that is typically <5% per day due to the absence of mechanical pumps (Tacon et al. 2002, 2004; Jory and Cabrera 2012). These water exchange practices are consistent with studies directly observing extensive farms in Indonesia (Florina and Sukardi 2012, Bunting et al. 2013). Furthermore, there is no evidence of mandatory escape prevention measures in the *P. monodon* farming industry. When these farm characteristics are combined with siting in coastal locations with high vulnerability to soil erosion, flooding events, and pond drainage at harvest, the escape risk for extensive *P. monodon* farms is considered moderate-high under Seafood Watch criteria and results in an Escape Risk factor score of 2 out of 10.

Intensive *L. vannamei* Farms

In general, the introduction of *L. vannamei* into Indonesia has prompted a move toward intensive culture systems with limited water exchange, the use of concrete-reinforced or polyethylene-lined ponds, and greater biosecurity measures (Briggs et al. 2004, 2005; Taw 2005; Nur 2007; Florina and Sukardi 2012). While farm management strategies with higher stocking rates may exchange as much as 40% of the pond volume on a daily basis (especially toward harvest) (Tacon et al. 2004), more typical daily exchange rates range from 5% to 25% (Jory and Cabrera 2012), and 2 auditing reports by ASC for the CP Prima Group indicate a daily exchange rate between 3.5% and 5.8% (Bussarin and Unger 2015, Bussarin and Unger 2015a).

In terms of regulatory management, intensive *L. vannamei* farms have a high adoption rate for best management practices (BMPs), where current management practices (i.e., ponds equipped with water gates) are in line with recommendations by various institutions, including the Ministry of Marine Affairs and Fisheries, the National Standardization Agency, NACA, SEAFDEC, and GlobalG.A.P. (Florina and Sukardi 2012). As a result, intensive *L. vannamei* farms are considered to be moderate escape-risk systems with active biosecurity measures and the resulting Escape Risk factor score for intensive *L. vannamei* farms is 4 out of 10.

Recapture and Mortalities

For farmed *L. vannamei*, recapture rates are generally considered to be poor (Anonymous 2015). For example, while 2 auditing reports by ASC describe the required use of trapping devices to prevent escapes, the auditors also note that the number of escapees are not consistently recorded (Bussarin and Unger 2015a, Bussarin and Unger 2015). For *P. monodon*, there is no information indicating that escapees are recaptured by farmers with any regularity. Furthermore, survival rates by both species after escape are known to be high (Benzie 2000; Briggs et al. 2004, 2005). With no specific recapture or mortality data available to indicate a significant reduction in the risk of escape in the shrimp farming industry, no adjustment was applied to the Escape Risk score for either extensive *P. monodon* or intensive *L. vannamei* farms.

F6.1b. Invasiveness

Invasiveness is a measure of the ability of an organism to spread from the site of primary introduction, to establish a viable population in a novel ecosystem, and to negatively affect biodiversity at an individual, community, or ecosystem level (Panov et al. 2008).

P. monodon

P. monodon are native to Indonesia and due to their ready availability in the region, broodstock and seed both have been historically sourced directly from the wild (Ardjosoediro and Goetz 2007). Due to overfishing and serious outbreaks of disease related to the use of wild seed, the vast majority of *P. monodon* farms now rely solely on first-generation hatchery-produced seed (i.e., wild broodstock parents) (FAO 2005). While smaller hatcheries are occasionally selling second-generation seed, large-scale commercial hatcheries produce only first-generation *P. monodon* larvae due to farmer preference (seed quality/fecundity is greatly reduced in third and fourth generation seed) (Anonymous 2015, Anonymous 2015a).

Although data is scant on the effects of escaped *P. monodon* on wild populations, a study in Thailand by Benzie (2000) found no conclusive evidence that aquaculture escapees had altered the genetic fitness of wild stocks of *P. monodon*. Escapees thus present a low level of concern for invasive impacts and score 4 out of 5 in Factor 6.1b, Part A. Furthermore, as low stocking densities in extensive *P. monodon* farms reduces the frequency of escapes (and the opportunity to cause invasive impacts), escapees are considered to compete for food, habitat, and breeding partners to some extent. For Part C of the Invasiveness factor, these conditions result in a score of 4 out of 5. When Part A and Part C are combined, the final 6.1b Invasiveness score for *P. monodon* escapes is 8 out of 10.

Overall, the Escape Risk and Invasiveness factors are combined, and with no adjustment for Recapture and Mortality, the environmental impacts of *P. monodon* escapes are considered moderate and result in a Criterion 6–Escape score of 5 out of 10.

L. vannamei
According to Briggs et al. (2005), the escape of *L. vannamei* from shrimp farms can be expected as a result of "accidental release during harvest and mass escapes during flooding events." Although recent sampling efforts by the Ministry of Marine Affairs and Fisheries have indicated that farmed *L. vannamei* are not present in coastal waters (Anonymous 2015a), the ongoing escape of *L. vannamei* into the wild can have similar impacts that are comparable to an established population.

Widely introduced in Indonesian waters (Briggs et al. 2005), the ecological impacts of escaped *L. vannamei* include competition with other species for space and food (Chavanich et al. 2008, Molnar et al. 2008, Senanan et al. 2009, Panutrakul et al. 2010), and studies in Thailand have concluded that ongoing *L. vannamei* escapes produce a persistent presence in waterbodies surrounding farm sites (Senanan et al. 2010). Additionally, food competition experiments in Thailand have shown that *L. vannamei* approach and capture food faster than native shrimp species (Senanan et al. 2010). These conditions suggest that a sustained, although not established (Senanan et al. 2009) *L. vannamei* presence may present potential impacts to local biodiversity (Panutrakul et al. 2010).

As a non-native shrimp species with the potential to generate an unestablished, yet persistent presence in the wild, the escape of farmed *L. vannamei* is considered to present a strong likelihood for ecological disturbance, resulting in a Non-native Species score of 0.5 out of 5 for Factor 6.1b, Part B. However, given that *L. vannamei* do not provide additional predation pressure or disturb breeding behavior in other native species, these conditions result in a score of 4.5 out of 5 for Part C of the Invasiveness factor. When Part B and Part C are combined, the final 6.1b Invasiveness score for *L. vannamei* escapes is 4.5 out of 10.

Overall, when the Escape Risk and Invasiveness factors are combined, and with no adjustment for Recapture and Mortality, the environmental impacts of escape are considered low-moderate and result in a Criterion 6–Escape score of 4 out of 10.

Escape Criterion—Conclusions and Final Score
There is an inherent level of risk for escape in pond-based shrimp aquaculture and the escape of farmed shrimp into the surrounding environment has been documented in Indonesia. Escapes can be expected as a result of water exchanges, accidental release during harvesting, during release from hatcheries, and during transport, as well as mass escape during flooding events and levee breaches.

As a species that is native to Indonesia, the escape of first-generation *P. monodon* presents a low level of risk for invasive impacts to wild counterparts. As a non-native species, *L. vannamei* escapees generate an unestablished, yet persistent presence in the wild from ongoing escapes, and thus pose a strong likelihood for ecological disturbance from competition for food and space between farmed and wild species.

With no direct data on recapture efforts or significant mortality levels in escaped shrimp, the overall Criterion 6 – Escape score is scored 5 out of 10 for farmed *P. monodon*, and 4 out of 10 for farmed *L. vannamei*.

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 waterbody.*
- *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.*

Extensive shrimp ponds, *P. monodon*

Pathogen and Parasite Parameters	Score	
C7 Biosecurity	2.00	
C7 Disease; pathogen and parasite Final Score	**2.00**	**RED**
Critical?	**NO**	

Intensive shrimp ponds, *L. vannamei*

Pathogen and Parasite Parameters	Score	
C7 Biosecurity	3.00	
C7 Disease; pathogen and parasite Final Score	**3.00**	**RED**
Critical?	**NO**	

In Indonesia, disease is one of the leading causes of mortality in farmed shrimp. *P. monodon* are known to be highly susceptible to both WSSV and YHV, and while *L. vannamei* broodstock are sourced from specific-pathogen-free (SPF) hatcheries, these shrimp are no longer safeguarded from contracting diseases once introduced to non-SPF environments. Currently, 5 of the 8 crustacean diseases listed by the World Organisation for Animal Health (OIE) have been documented in either farmed *P. monodon* or *L. vannamei*. Despite the wide use of best management practices (BMPs) throughout the industry to combat the occurrence of disease and the frequency of outbreaks, the spread of shrimp pathogens within Indonesia continues to occur with regularity due to weak regulatory structures and lax enforcement. Furthermore, communications with an industry expert indicate that there is a positive correlation between the number of neighboring shrimp farms with infected stock and the incidence of disease in wild crustaceans within the surrounding area. These conditions result in a low Criterion 7–Disease scores of 2 out of 10 for *P. monodon* and 3 out of 10 for *L. vannamei* farms in Indonesia.

Justification of Ranking

Since the 1980s, shrimp production in Asia has been characterized by a series of viral pathogens that have caused significant losses to the region's shrimp farming industries (Briggs et al. 2004, 2005). In addition to poor soil and water quality, disease also constitutes one of the leading causes of mortality in farmed shrimp (Kautsky et al. 2000, Supriyadi and Rukyani 2000). Both bacterial and viral shrimp pathogens have had a devastating effect on shrimp farming worldwide, and have emerged as a major constraint in shrimp aquaculture, especially viral diseases for which there are no therapeutic cures (Budhiman 2005, Nur 2007, Ardjosoediro and Goetz 2007, Taukhid and Nur'aini 2009). On a regional scale, it is widely believed that the three most economically significant viral pathogens (YHV, WSSV, and TSV) have been established in Asia through the irresponsible introduction of live shrimp (Briggs et al. 2005) (See Criterion 10X for further information on the Escape of Unintentionally Introduced Species).

P. monodon production in Indonesia has historically suffered from high levels of pathogen-related infections and mortality, leading shrimp farms to fail 40%–50% of the time (Yi et al. 2009). In South and East Sulawesi, it has been reported that thousands of ponds have been abandoned due to the prevalence of disease (Martin 2008). In the late 1990s, outbreaks of YHV and WSSV left the Indonesian shrimp farming industry in such severe decline that *L. vannamei* was adopted in 2001 as a more reliable alternative (Briggs et al. 2004, 2005; Budhiman 2005; Nurdjana 2006; Sugama 2006; Lymer et al. 2008; Afero 2009; Yi et al. 2009).

Pathogens in Shrimp Aquaculture

P. monodon are known to be highly susceptible to both WSSV and YHV but not to IHHNV or TSV, and while *L. vannamei* are generally considered to be more robust than other white shrimp, they are in fact highly susceptible to WSSV, TSV, IMNV, and are carriers of IHHNV (Briggs et al. 2004, 2005; FAO 2006; GAIN 2007; Ardjosoediro and Goetz 2007; Taukhid and Nur'aini 2009; Senapin et al. 2011). While WSSV and YHV are the most lethal pathogens for both *monondon* and *L. vannamei* (Flegel et al. 2014), various *Vibrio* sp. have also been implicated in shrimp pond culture as well as in hatchery systems (Supriyadi and Rukyani 2000, Widigdo and Pribadi 2005).

The major diseases affecting the shrimp farming industry in Indonesia are listed in the following table:

Major diseases	Type	*P. monodon*	*L. vannamei*	Reference
Yellowhead Virus (YHV)	viral	y	y	Briggs et al. 2005 Walker and Winton 2010
White spot syndrome (WSSV)	viral	y	y	Widigdo and Pribadi 2005 Sugama 2006 Taukhid and Nur'aini 2009
Taura syndrome (TSV)	viral	n	y	Widigdo and Pribadi 2005 Sugama 2006 Taukhid and Nur'aini 2009
Infectious hypodermal and haematopoietic necrosis (IHHNV)	viral	y	y	Widigdo and Pribadi 2005 Sugama 2006 Ardjosoediro and Goetz 2007 Taukhid and Nur'aini 2009
Infectious myonecrosis (IMNV)	viral	y	y	Sugama 2006 Taukhid and Nur'aini 2009
P. monodon Baculovirus	viral	y	n	Widigdo and Pribadi 2005

(MBV)				Ardjosoediro and Goetz 2007
Hepatopancreatic parvovirus (HPV)	viral	y	n	Ardjosoediro and Goetz 2007 Flegel et al. 2014
Vibriosis (Tail rot, black gill, WFD, etc.)	bacterial	y	y	Widigdo and Pribadi 2005
Haplosporidian parasites	protozoan	n	y	Utari et al. 2012

Currently, the World Organisation for Animal Health (OIE) lists 8 diseases of crustaceans in their Aquatic Animal Health Code (OIE 2015). Considered to be transmittable and of significant socio-economic and public health importance, 5 of these diseases have been documented in Indonesia:

1. Yellow head virus (YHV) is the most virulent of shrimp pathogens, commonly causing total crop loss within several days of the first signs of disease in a pond. It first emerged in cultured *P. monodon* in Thailand in 1990 and has since been reported in most major shrimp farming countries in Asia, including Indonesia (Walker and Winton 2010). Although losses due to YHV continue to occur, the severity and frequency of outbreaks declined sharply between 1994 and 1996 when WSSV became the prime cause of mortality in the *P. monodon* farming industry (Briggs et al. 2005, Widigdo and Pribadi 2005).
2. Major losses of *P. monodon* in 1996 and *L. vannamei* in 2002 were attributed to WSSV (Widigdo and Pribadi 2005, Nur 2007), which is triggered by the onset of seasonally heavy rain and subsequent low temperatures (Taw 2010).
3. Since the time TSV was first documented in East Java in 2002, it has been associated with severe epizootics in both farmed *L. vannamei* and *P. monodon* (Widigdo and Pribadi 2005, Sugama 2006, Taukhid and Nur'aini 2009).
4. IHHNV has existed in Asia for some time without detection due to its insignificant effects on *P. monodon*, where tolerance is suspected of having developed over an extended period of time (Briggs et al. 2005). Reported for both cultured and wild penaeid species throughout the Indo-Pacific region, declines in growth rate and survival of cultured *L. vannamei* in Indonesia are due to the stress of high IHHNV viral loading in the broodstock and the passing of this disease to offspring (Sugama 2006).
5. In 2006, the first documented disease outbreaks of IMNV in Asia occurred in Indonesia (Briggs et al. 2004; Widigdo and Pribadi 2005; Sugama 2006; Taukhid and Nur'aini 2009; Shishehchian 2011; Senapin et al. 2007, 2011, 2013; SFP 2013) and is the most recent major viral disease to emerge in farmed shrimp (Walker and Winton 2010). Disease outbreaks in *L. vannamei* are characterized by gross signs of whitened abdominal muscles and by slow mortality reaching up to 70% (Senapin et al. 2007, 2011). Since there is no effective treatment for IMNV infection, shrimp farmers can protect their farms and shrimp only by preventing the disease (Taukhid and Nur'aini 2009).

It should be noted that early mortality syndrome (EMS), which is the common name for the bacterial disease, necrotising hepatopancreatitis (NHP), has yet to be discovered in Indonesia (Thompson 2013, Valderrama et al. 2014). EMS is a highly infectious shrimp disease capable of causing 100% mortality in farms (Nikolik and Kumar 2013). EMS was first detected in China in 2009, and has spread to Vietnam, Malaysia, and Thailand and was most recently detected in Mexico (Undercurrent News 2013). While an outbreak has yet to occur in Indonesia, the potential for transmission of the disease remains high given its rapid spread throughout Southeast Asia.

Despite the various codes and shrimp farming guidelines that have been developed and agreed upon by various global (ICES, OIE, FAO, etc.) and regional (NACA, SEAFDEC and ASEAN) organizations, the most effective disease control measures to date involve the use of domesticated SPF shrimp stocks and their cultivation in biosecure settings under management practices aimed at optimum (not maximum) production (Flegel et al. 2014).

Use of Certified SPF and SPR Shrimp

In response to the viral pandemics of the early 1990s, the widespread adoption of imported SPF *L. vannamei* is credited with preventing the collapse of the shrimp farming industry in Southeast Asia (Briggs et al. 2004, 2005; Lightner 2011). Since their introduction in 2001, SPF *L. vannamei* have been widely farmed in Indonesia (Nur 2007, Utari et al. 2012). Importantly, however, once SPF *L. vannamei* are introduced to growout ponds, these shrimp are as susceptible to disease as non-SPF shrimp. Although specific pathogen resistant (SPR) *L. vannamei* have been developed, only TSV-resistant stocks have been utilized in Indonesia (Briggs et al. 2004, 2005).

Impact of Shrimp Farm Pathogens on Wild Species

While there is very little recent data concerning their impact on wild stocks, it has been reported that pathologic viruses in farmed shrimp can be transmitted to native, wild populations (Overstreet et al. 1997, Subcommittee on Aquaculture Joint (JSA) 1997) and there is documented evidence of transmission in several countries. Introduced by diseased farm stock, it is known that YHV now occurs in wild shrimp throughout Asia, TSV occurs in the U.S., IHHNV in Mexico, and WSSV in both Asia and Latin America (Briggs et al. 2005). Furthermore, direct evidence shows that TSV in farmed *L. vannamei* has made the jump across species to local stocks of *P. monodon,* specifically in Thailand (Briggs et al. 2005). In Indonesia, an industry expert also indicates that wild crustaceans in proximity to shrimp farms are often infected by viral diseases such as WSSV and IMNV, showing a positive correlation between the number of neighboring shrimp farms with infected stock and the incidence of disease in wild crustaceans within the surrounding area (Anonymous 2013).

While there is no peer-reviewed literature on disease interactions between farmed and wild shrimp in Indonesia, the documented disease transmission in several other shrimp farming regions and the amplification of disease-related mortalities observed by one expert indicate that the current disease prevalence and intensity levels in Indonesian shrimp farms constitutes a significant risk for wild stocks. Given the growing nature of the Indonesian shrimp farming industry and the discharge of water without any relevant treatment (Taw 2005, Florina and Sukardi 2012, Bussarin and Unger 2015, Bussarin and Unger 2015a), the transfer of disease from farmed shrimp to wild stocks is considered a high concern under Seafood Watch criteria.

Disease Criterion—Conclusions and Final Score

Overall, a review of the literature and communications with an industry expert provide evidence of disease transmission from farmed shrimp to wild species and a subsequent increase in mortality due to infection from farm-derived pathogens. Although government agencies and the private sector have developed biosecurity protocols and BMP materials, the prevalence and diversity of pathogens found throughout the *P. monodon* and *L. vannamei* farm industries indicate a high potential for ongoing disease transmission between shrimp ponds and susceptible wild species in the surrounding environment. Although the adoption of imported SPF *L. vannamei* is credited with preventing the collapse of Indonesian shrimp farming, their use has not prevented the ongoing presence of pathogens in shrimp ponds and the risk of disease transmission to wild stocks. Under these conditions, the final score for the Criterion 7–Disease scores of 2 out of 10 for *P. monodon* and 3 out of 10 for *L. vannamei* farms in Indonesia.

Criterion 8: Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for ongrowing 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.*

Extensive shrimp ponds, *P. monodon*

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**

Intensive shrimp ponds, *L. vannamei*

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**

In Indonesia, *P. monodon* farms are 100% reliant on fully exploited, if not overexploited, native shrimp populations due to an industry-wide dependence on wild-caught individuals for broodstock. Although ~90% of the *P. monodon* seed sold in Indonesia are produced in hatcheries, wild broodstock are required and these shrimp are not considered independent from wild stocks under Seafood Watch criteria. *L. vannamei* farms are considered to be 100% reliant on hatchery production for both broodstock and seed stock. Based on their degree of independence from wild stocks, the final score for Criterion 8 – Source of Stock is 0 out of 10 for the *P. monodon* farming industry and 10 out of 10 for the *L. vannamei* farming industry.

Justification of Ranking

Extensive *P. monodon* Farms

Geographically, Indonesia is located in an area where major *P. monodon* resources have been observed in coastal waters (Ardjosoediro and Goetz 2007). Nonetheless, due to overfishing and the outbreak of white spot disease in shrimp nursery grounds in the 1990s (Briggs et al. 2004, 2005; Lymer et al. 2008), the use of wild seed has been significantly reduced and most *P. monodon* farms now rely almost completely on hatchery-reared seed (FAO 2005).

The first shrimp hatchery in Indonesia was commissioned in the early 1970s in Makassar (South Sulawesi) followed by another in Jepara (Central Java) (Poernomo 2004). Approximately 90% of the *P. monodon* seed sold in Indonesia are now produced in hatcheries while the remaining seed are sourced directly from the wild (Ardjosoediro and Goetz 2007, Anonymous 2015). The broodstock used to produce these hatchery-reared seed, however, continue to be sourced entirely from wild stocks (Gräslund and Bengtsson 2001, Ardjosoediro and Goetz 2007, Yi et al. 2009, Anonymous 2015, Anonymous 2015a). Although research for domesticating broodstock is in progress, wild *P. monodon* broodstock are currently sourced from several regions in Indonesia including Aceh, East Kalimantan, Lombok, and Cilacap (Anonymous 2015, Anonymous 2015a).

Many stock assessments have been carried out on the status of penaeid shrimp resources in Indonesia, including periodic reviews by the National Commission of Marine Fish Stock Resources. In reviewing these works, a report by Gillett (2008) concluded that there does not appear to be much potential for expansion of shrimp catches in Indonesia and, in many areas, shrimp resources appear to be considerably overexploited; a situation exacerbated by illegal fishing activity and poor statistical information. Another more recent workshop assessing shrimp stocks in Southeast Asia indicates that *P. monodon* resources were being fully exploited if not overexploited (FAO 2011). Due to the stated preference for first-generation hatchery-raised post-larvae, it is therefore considered that ongoing, consistent collection of wild *P. monodon* for broodstock contributes to declines in wild populations.

Intensive *L. vannamei* Farms
In Indonesia, *L. vannamei* are a non-native species and hatchery-raised broodstock are both imported and grown domestically in hatcheries within the country (Briggs et. al. 2005, NALO 2006, Ardjosoediro and Goetz 2007, GAIN 2007, Yi et al. 2009, Shishehchian 2011, Anonymous 2015a). There are three main sources of *L. vannamei* broodstock in Indonesia (Budhiman 2005, Ardjosoediro and Goetz 2007,Yi et al. 2009, Shishehchian 2011):

1. Imports of tank-reared SPF (Hawaii, also Florida, but reduced since 2009) and non-SPF broodstock (Taiwan)
2. Government-established broodstock hatcheries
3. Cultured shrimp matured from grow-out ponds (use of local broodstock began as early as 2002)

Although 2 recent audit reports for the CP Prima Group indicate that *L. vannamei* broodstock are still sourced from hatcheries in Hawaii and Florida (Bussarin and Unger 2015a, Bussarin and Unger 2015), it has been the intent of the Indonesian government for several years to increase the domestic production of *L. vannamei* broodstock in an effort to decrease the high costs associated with imports (Shishehchian 2011). As a result, both national and regional broodstock centers have been established in Mid and East Java as well as South Sulawesi, Aceh, and in Bali (NALO 2006, Sukardi 2008, Shishehchian 2011).

Source of Stock Criterion—Conclusions and Final Score
In Indonesia, *P. monodon* farms are considered to be 100% reliant on fully exploited, if not overexploited, native shrimp populations, due to an industry-wide dependence on wild-caught broodstock. Although there is currently no data on the extent of broodstock collection, these shrimp are sourced from significantly exploited wild-capture fisheries and *P. monodon* seed produced in hatcheries are not considered independent from wild stocks under Seafood Watch criteria. In contrast, the *L. vannamei* farming industry is considered to be 100% reliant on hatcheries for both broodstock and farm stock.

Overall, these conditions result in a low Criterion 8 – Source of Stock score of 0 out of 10 for the *P. monodon* farming industry and a high score of 10 out of 10 for *L. vannamei* farming industry.

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.

Extensive shrimp ponds, *P. monodon*

Wildlife and Predator Mortality Parameters	Score	
C9X Wildlife and predator mortality Final Score	**-5.00**	**YELLOW**
Critical?	NO	

Intensive shrimp ponds, *L. vannamei*

Wildlife and Predator Mortality Parameters	Score	
C9X Wildlife and predator mortality Final Score	**-5.00**	**YELLOW**
Critical?	NO	

A variety of native wildlife species are associated with shrimp ponds in Indonesia, and many are deterred or eliminated using physical and chemical control methods. While interactions between wildlife and shrimp farms have been frequently observed, there is little recently published, peer-reviewed literature that specifically addresses mortality rates. The lack of statistical data available for both *P. monodon* and *L. vannamei* farm-related wildlife mortalities results in a precautionary approach to scoring this criterion. Under Seafood Watch criteria, the impact of shrimp farms on low-productivity species (predatory fish, amphibians, reptiles, birds) are thus considered to be unknown, and farm-related mortalities of competitive species (polychaetes, insects, shrimps, snails, herbivorous fishes) and destructive pests (mud crabs) are not considered to be significant (regardless of differing mortality rates between *P. monodon* and *L. vannamei* farms), due to these species' highly productive natures and large population size. As such, the same penalty score of -5 out of -10 is assessed to both extensive *P. monodon* farms and intensive *L. vannamei* farms for Exceptional Criterion 9X–Wildlife Mortalities.

Justification of Ranking

While interactions between marine wildlife and shrimp ponds have been observed (Taslihan and Sunaryanto 1990), there is little recently published, peer-reviewed literature that specifically addresses this issue. For Indonesian shrimp farming, pest control is driven primarily by disease concerns (Taw 2010) and the tendency for farmers to follow best practices, which directly impact the value of the farm's final shrimp product (Florina and Sukardi 2013).

Wildlife Species in Shrimp Ponds

A variety of native wildlife are found in ponds other than the cultured shrimp species, and many are eliminated because they are likely to lower productivity by consuming shrimp, by competing for the use of available resources, or by causing damage to the ponds (Taslihan and Sunaryanto 1990). Based on these types of losses, pests can be categorized either as a predator, competitor, or a destructive pest (Table 8).

Pest type	Species	Reference
Predators		
Fishes	Hawaiian ladyfish (*Elops hawaiensis*)	Taslihan and Sunaryanto 1990
	Indo-Pacific tarpon (*Megaslops cyprinoides*)	Taslihan and Sunaryanto 1990
	Crescent Perch (*Therapon jarbua*)	Taslihan and Sunaryanto 1990
	Barramundi (*Lates calcarifer*)	Taslihan and Sunaryanto 1990
	Grouper (*Epinephelus tetradactylum*)	Taslihan and Sunaryanto 1990
	Threadfin (*Eleutheronema* sp.)	Taslihan and Sunaryanto 1990
Amphibians	Brown frog (*Rana* sp.)	Taslihan and Sunaryanto 1990
Reptiles	Asian bockadam snake (*Carberus rhynchops*)	Taslihan and Sunaryanto 1990
	Water monitor lizards (*Varanus* sp.)	Pers. comm., Peet 2015
Birds	Stork (*Ciconidae* fam.)	Taslihan and Sunaryanto 1990
	Duck (*Anatidae* fam.)	Taslihan and Sunaryanto 1990
	Ibis (*Plegadidae* fam.)	Taslihan and Sunaryanto 1990
Competitors		
Polychaetes	(*Dendronereis* sp.)	Taslihan and Sunaryanto 1990
Insects	Chironomid larvae	Taslihan and Sunaryanto 1990
Shrimps	Banana shrimp (*Penaeus merguiensis*)	Taslihan and Sunaryanto 1990
	Speckled shrimp (*Metapenaeus monoceros*)	Taslihan and Sunaryanto 1990
	Mysid (*Mesopodopsis* sp.)	Taslihan and Sunaryanto, 1990 Gräslund and Bengtsson 2001
Snails	Horn snail (*Cerithidae*)	Taslihan and Sunaryanto 1990
Fishes	Tilapia (*Tilapia mossambica*)	Taslihan and Sunaryanto 1990
	Flathead grey mullet (*Mugil sephalus*)	Taslihan and Sunaryanto 1990
	Blue panchax (*Aplocheilus panchax*)	Taslihan and Sunaryanto 1990
	Spotted scat (*Scatophagus argus*)	Taslihan and Sunaryanto 1990
Destructive pests		
Crustaceans	Mud crab (*Scylla serrata*)	Taslihan and Sunaryanto 1990

Table 8: Pest species commonly found in Indonesian *P. monodon* farms

Pest Species Commonly Found in Indonesian *L. vannamei* Farms

Given that intensive *L. vannamei* farms are located in the same geographic area as extensive *P. monodon* farms, and often occupying the same site as previous *P. monodon* farms, pest species are considered to be the same in both shrimp farming industries.

Physical Control Methods

Physical methods for pest control are generally passive and implemented during the preparation period, but can also be undertaken during growout (Table 9).

Physical control method	Purpose	Reference
Pond-bottom drying	Killing all organisms within a pond, including eggs and larvae	Taslihan and Sunaryanto 1990 (*P. monodon*) ADB et al. 2007 (*P. monodon*) Florina and Sukardi 2012 (*L. vannamei*) Bunting et al. 2013 (*P. monodon*)
Dike/berm enhancement	Preventing entry into ponds	Taslihan and Sunaryanto 1990 (*P. monodon*)
Screening water supply	Preventing entry into ponds	Taslihan and Sunaryanto 1990 (*P. monodon*) ADB et al. 2007 (*P. monodon*) Taw 2010 (*L. vannamei*)
Direct capture	Physical removal	Taslihan and Sunaryanto 1990 (*P. monodon*) Florina and Sukardi 2012 (*L. vannamei*)
Crab fence	Prevent crab entry	Taslihan and Sunaryanto 1990 (*P. monodon*) Taw 2010 (*L. vannamei*)
Bird scare line	Prevent bird entry	Taslihan and Sunaryanto 1990 (*P. monodon*) Taw 2010 (*L. vannamei*)

Table 9: Physical pest control methods in extensive *P. monodon* and intensive *L. vannamei* farms.

Chemical Control Methods

While both natural and synthetic chemicals are used to control predators and wildlife in Indonesia, there is generally no clear distinction between application practices for different chemicals in Southeast Asia (i.e., chlorine can be used as both a disinfectant and a piscicide) and farmers have used products differently than intended by the producer (Supriyadi and Rukyani 2000, Gräslund and Bengtsson 2001).

After ponds have been allowed to dry completely, intensive *L. vannamei* farmers typically apply disinfectant to control pests, and treated water from reservoirs is used to fill the ponds during the pre-stocking period as well as during grow-out (Florina and Sukardi 2012). Similarly, extensive *P. monodon* farmers treat pond water with pesticides and saponin (plant-derived toxin) before stocking to eradicate predators and competitors (Bunting et al., 2013). Furthermore, shrimp farmers in Aceh are known to check for the presence of water monitors and subsequently poison them (pers. comm., Peet, 2015).

Wildlife Management

At the national level, Government Regulation #7 (1999) provides a list of protected flora and fauna in Indonesia (US-AID, 2015). Although there are no specific matches between the wildlife species listed in Government Regulation #7 (1999) and those mentioned in Table 4, eight species of water monitor lizards are protected and the species purposefully killed at shrimp ponds are unknown.

In *L. vannamei* farms, the overall BMP adoption level for pest management during pond preparation is high for intensive farms and low for traditional farms (Florina and Sukardi 2012). As BMPs for shrimp aquaculture are not a legal instrument, the implementation of these management measures is not mandatory and they are not actively enforced (pers. comm. Peet 2015). While extensive *P. monodon* BMPs suggest avoiding the use of synthetic pesticides (ADB et al. 2007), reports indicate that these chemicals are still being used (Nur 2007, Ardjosoediro and Goetz 2007, Bunting et al. 2013), and that BMP adoption is generally variable in extensive shrimp farms. Furthermore, the usefulness of some best management practices is debatable as bird scare lines are not considered effective management (Pers. comm. Peet 2015).

Although wildlife management measures are present at the national level and are also promoted in voluntary BMPs, neither of these regulatory tools specifically require monitoring or reporting wildlife mortalities. Given the lack of wildlife mortality data for Indonesian shrimp farming, the impacts to farm predators, competitors, and pests is considered unknown in this Seafood Watch report.

Wildlife and Predator Mortalities Criterion—Conclusions and Final Score

In Indonesia, a variety of wildlife species are present in shrimp aquaculture. While interactions between marine wildlife and shrimp ponds have often been observed, there is little recently published, peer-reviewed literature that specifically addresses this issue. The lack of data available for both *P. monodon* and *L. vannamei* farm-related wildlife mortalities results in a precautionary approach to scoring this criterion. In this assessment, the impact of shrimp farms on low-productivity species (predatory fish, amphibians, reptiles, birds) are unknown (warranting a score of -6). Farm-related mortalities of competitive species (polychaetes, insects, shrimps, snails, herbivorous fishes) and destructive pests (mud crabs) are not considered to be significant given the highly productive nature and large population size of each of these species (which warrants a score of -4).

Note that this is an Exceptional criterion and the scoring range is from 0 (no concern) to -10 (very high concern). Accounting for the different types of wildlife species affected, the final score for this Exceptional Criterion is a penalty of -5 out of -10 (between -6 and -4) for both extensive *P. monodon* farms and intensive *L. vannamei* farms in Indonesia.

Criterion 10X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species other than the principle 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.

Extensive shrimp ponds, *P. monodon*

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

Intensive shrimp ponds, *L. vannamei*

Escape of Unintentionally Introduced Species Parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	8.00	
F10Xb Biosecurity of source/destination	4.00	
C10X Escape of unintentionally introduced species Final Score	**-1.20**	**GREEN**

In the *P. monodon* farming industry, broodstock and seed stock are generally sourced from different areas than the hatchery or farm site location. Although wild *P. monodon* broodstock may be transported some distance from domestic fishing grounds to hatcheries, and seed stock from hatcheries to growout ponds, these movements are typically local or between neighboring provinces and are not considered to represent trans-waterbody live animal shipments between ecologically distinct waterbodies. As such, no penalty score was applied to the *P. monodon* farming industry for Criterion 10X (score of 0 out of -10). For *L. vannamei* culture, although guidelines and regulatory frameworks have been established to restrict the movement of foreign shrimp, illegal international imports of *L. vannamei* broodstock and the inadequate biosecurity measures surrounding non-SPF broodstock produced by the private sector create an environment that is vulnerable to unintentionally transporting and propagating pathogens. Nonetheless, the current industry-wide lack of reliance on overseas sources (15%) and the absence of trans-waterbody movements greatly reduces the potential for the escape of unintentionally introduced species. These conditions result in a final C10X–Escape of Unintentionally Introduced Species penalty score of -1.2 out of -10 for *L. vannamei* culture.

Justification of Ranking

P. Monodon

Factor 10Xa International or Trans-waterbody Live Animal Shipments

Although farmed *P. monodon* in Indonesia have been sourced internationally in the past (Briggs et al. 2005), small-scale shrimp farmers generally lack the financial capacity to import farm stock (Florina and Sukardi 2012, pers. comm. Peet 2015) and more recent literature indicates that *P. monodon* broodstock are sourced entirely from wild stocks within Indonesian waters (Ardjosoediro and Goetz 2007, Yi et al. 2009). These wild-caught broodstock are usually sourced from a "similar province that is close" to the hatchery (Anonymous 2015a). For farm stock, farmers typically source their shrimp seed from local hatcheries (Yi et al. 2009).

Overall, although *P. monodon* broodstock may be transported some distance from fishing grounds to hatcheries, and seed stock from hatcheries to growout ponds, these movements are not considered to represent trans-waterbody live animal shipments between ecologically distinct waterbodies. As such, no penalty score was applied to the *P. monodon* farming industry for Criterion 10X (score of 0 out of -10).

L. vannamei

Factor 10Xa International or Trans-waterbody Live Animal Shipments

Although licensed imports of SPF *L. vannamei* from the United States have been allowed in Indonesia since 2001, there is clear evidence that the international demand for SPF broodstock is far beyond the ability of a limited number of producers to fulfill (Briggs et al. 2005). To reduce the shrimp farming industry's reliance on imports of expensive, and often inconsistent, broodstock supplies from the U.S., the Ministry of Maritime Affairs and Fisheries developed their own locally-adapted *L. vannamei* strain in 2009 (Indu Vannamei Nusantara I, or IVN1) and has since actively promoted its use (Merican 2009, Merican 2015). As a result, of the 900,000-965,000 broodstock purchased annually by the shrimp farming industry, only ~15% (140,000) were sourced from overseas in 2010 (Merican 2009, JP 2010). Furthermore, the transfer of seed stock from hatcheries to growout ponds is not considered to represent trans-waterbody live animal movements between ecologically distinct waterbodies. For Factor 10Xa, the *L. vannamei* farming industry's low reliance on internationally-sourced broodstock shipments and lack of trans-waterbody movements results in a score of 8 out of 10.

Factor 10Xb Biosecurity of the Source/Destination

Biosecurity of *L. vannamei* broodstock Sources

In Indonesia, *L. vannamei* broodstock are obtained from several different sources, including SPF hatcheries in the United States, SPF hatcheries in Indonesia, non-SPF hatcheries in Indonesia, and through illegal imports:

SPF Hatcheries (United States)

The Hawaii Shrimp Surveillance & Certification Program is managed by the Hawaii Department of Agriculture (HDOA). Participating facilities undergo rigorous monitoring and must consecutively test negative for specific pathogens over a 24-month period to receive certified SPF status.

SPF Hatcheries (Indonesia)

Since 2009, the Ministry of Maritime Affairs and Fisheries has actively promoted the use of a locally-developed *L. vannamei* strain (IVN1) (Merican 2009, Merican 2015). Developed to reduce Indonesia's reliance on imported SPF *L. vannamei*, IVN1 are cultured in facilities with strong biosecurity measures where shrimp are certified free of WSSV, IMNV, TSV, and IHHNV (Merican 2014).

Non-SPF Hatcheries (Indonesia)

In addition to the broodstock imported from the United States and those supplied by the Indonesian government, the private sector has also been known to produce *L. vannamei* broodstock locally (Yi et al. 2009). Sourced from growout ponds, locally produced broodstock are significantly less expensive than imports (82%–84% cheaper–Pulauhantu 2009), but their production often overlooks SPF guidelines and farmers may be unaware that locally produced broodstock are potential disease carriers (Budhiman 2005, GAIN 2007, Soedrijanto et al. 2013). Therefore, the movement of local, non-SPF broodstock can still play a major role in the spread of shrimp pathogens (Briggs et al. 2005, Widigdo and Pribadi 2005, Taukhid and Nur'aini 2009).

Illegal Imports of *L. vannamei*

Universally, importation and regional transportation of species for aquaculture purposes carries the risk of importing associated pathogens (Kautsky et al. 2000). For penaeid shrimp, this risk is especially high for viral diseases (Briggs et al. 2005, Utari et al. 2012). On a regional scale, imports of cheaper, non-certified disease-free shrimp have resulted in the introduction of viral pathogens in a number of Asian countries, including Indonesia. According to Briggs et al. (2005), it is widely believed that the three most economically significant viral pathogens (YHV, WSSV, and TSV) have been established in Asia through the irresponsible introduction of live shrimp.

Although guidelines (Revitalization of Aquaculture program) and regulatory frameworks (Ministerial Decree: 08/MEN/2004: Procedure to Introduce New species and New Variety of Fish to Indonesia Territory; SE DGA No. 213/DPB4/PB.420.D4/I/04: Live Shrimp Movement Free from TSV and WSSV) have been established to restrict the movement of *L. vannamei* since their introduction in 2001 (Taw 2010), the private sector nonetheless has imported stocks of illegal, and often disease carrying, *L. vannamei* into Asia from many international locations (Briggs et al. 2004, 2005). As a result, there is widespread recognition that these unregulated imports represent the primary channel for introducing and spreading non-native pathogens between shrimp farming regions (Briggs et al. 2005, Taukhid and Nur'aini 2009, pers. comm. Peet 2015), and disregard for this danger has been directly responsible for TSV and IMNV transmission to Indonesia from abroad (Taukhid and Nur'aini 2009, Walker and Winton 2010, Senapin et al. 2007, 2011).

Overall, SPF *L. vannamei* broodstock sourced from the U.S. and Indonesian government are considered to be tank-based hatchery systems with strong biosecurity measures for inputs and outputs (warranting a score of 8), while non-SPF *L. vannamei* broodstock sourced from growout ponds and illegal imports are considered to be much more vulnerable to unintentional introductions (which warrants a score of 4 and 0, respectively). Accounting for the different sources of *L. vannamei* broodstock and the unknown percentage of national production of several contributing sources (both SPF and non-SPF hatcheries in Indonesia and illegal imports), the final biosecurity score is 4 out of 10 (average between 0 and 8).

Biosecurity of Intensive *L. vannamei* Farms
In general, the introduction of *L. vannamei* into Indonesia has prompted a move toward intensive culture systems with limited water exchange, the use of concrete-reinforced or polyethylene-lined ponds, and greater biosecurity measures (Briggs et al. 2004, 2005; Taw 2005; Nur 2007; Florina and Sukardi 2012). While farm management strategies with higher stocking rates may exchange as much as 40% of the pond volume on a daily basis (especially toward harvest) (Tacon et al. 2004), more typical daily exchange rates range from 5%–25% (Jory and Cabrera 2012), and 2 auditing reports by ASC for the CP Prima Group indicate a daily exchange rate between 3.5% and 5.8% (Bussarin and Unger 2015, Bussarin and Unger 2015a). In terms of regulatory management, intensive *L. vannamei* farms have a high adoption rate for best management practices (BMPs), where current management practices (i.e., ponds equipped with water gates) are in line with recommendations by various institutions, including the Ministry of Marine Affairs and Fisheries, the National Standardization Agency, NACA, SEAFDEC, and GlobalG.A.P. (Florina and Sukardi 2012). As a result, intensive *L. vannamei* farms are considered to be moderate escape-risk systems with active biosecurity measures and the resulting biosecurity score is 4 out of 10 for the destination of *L. vannamei* farm stock.

Under the assumption that more robust biosecurity measures at either the source or destination farmed *L. vannamei* reduces the overall risk of unintentional introductions, the higher score between the source and destination is applied under Seafood Watch criteria. As such, Factor 10Xb score of 4 out of 10 was applied to intensive *L. vannamei* farms.

Combining Factor 10Xa and 10Xb results in an overall penalty score of -1.2 out of -10 for *L. vannamei* farms in Indonesia.

Escape of Introduced Species Criterion—Conclusions and Final Score
The scoring structure for this criterion combines the percentage of production reliant on international or trans-waterbody movements of live shrimp with the biosecurity of either the source or the destination of those shipments (whichever is higher). Note this is an Exceptional criterion and the scoring range is from 0 (no concern) to -10 (very high concern).

In the *P. monodon* farming industry, farmers typically source their shrimp stocks from hatcheries within the country, which are often local to the farm. Given the absence of international or trans-waterbody live animal shipments, no penalty score was applied to *P. monodon* farming industry under Criterion 10X.

Although imports of supposedly disease-free seed and broodstock are allowed under government supervision, the difficulty and expense involved with such introductions, combined with impatience from shrimp farmers, has circumvented national and international biosecurity measures and illegally brought in *L. vannamei* stocks that are not SPF-certified. Domestically, while Indonesian hatcheries that produce 'Indu Vannamei Nusantara I' have implemented strong biosecurity protocols, all other *L. vannamei* hatcheries lack the biosecurity measures to produce SPF-certified shrimp (i.e., sourcing from growout ponds). As a result, the biosecurity surrounding the use of a non-native shrimp species with pond systems creates an environment that is vulnerable to unintentionally transporting and propagating pathogens. Nonetheless, given the lack of international shipments (15%) and the absence of trans-waterbody movements in the current *L. vannamei* farming industry, a final penalty score of -1.2 out of -10 is applied to C10X–Escape of Unintentionally Introduced Species.

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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.

P. MONODON, EXTENSIVE SHRIMP PONDS

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	7.5	7.5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
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	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	2.5	2.5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**25**

C1 Data Final Score	3.125	RED

Criterion 2: Effluents

Factor 2.1a–Biological waste production score

Protein content of feed (%)	0
eFCR	0
Fertilizer N input (kg N/ton fish)	97.77
Protein content of harvested fish (%)	18.5
N content factor (fixed)	*0.16*
N input per ton of fish produced (kg)	97.77
N in each ton of fish harvested (kg)	29.6
Waste N produced per ton of fish (kg)	**68.17**

Factor 2.1b–Production System discharge score

Basic production system score	0.51

Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score	**0.51**

5
1 % of the waste produced by the fish is discharged from the farm

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?	Partly	0.25
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?	No	0
3–Do the control measures address or relate to the cumulative impacts of multiple farms?	Partly	0.25
4–Are the limits considered scientifically robust and set according to the ecological status of the receiving waterbody?	No	0
5–Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc?	No	0
		0.5

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?	Partly	0.25
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
		0.25

F2.2 Score (2.2a*2.2b/2.5)	**0.05**

C2 Effluent Final Score	**3.00**	**RED**
	Critical?	NO

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**4**

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?	No	0
2–Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	No	0
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Mostly	0.75
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)	Mostly	0.75
5–Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Moderatel y	0.5
		2

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?	Partly	0.25
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?	No	0
4–Is the enforcement process transparent–e.g., public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	No	0
5–Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Partly	0.25
		0.75

F3.2 Score (2.2a*2.2b/2.5)	**0.60**

C3 Habitat Final Score	**2.87**	**RED**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	4.00	
C4 Chemical Use Final Score	**4.00**	**Yellow**
Critical?	NO	

Criterion 5: Feed

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

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	**2**

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	**2**

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	**5.00**	**YELLOW**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	2.00	
C7 Disease; pathogen and parasite Final Score	**2.00**	**RED**
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	**-5.00**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	10.00	
C10Xb Biosecurity of source/destination	N/A	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

L. VANNAMEI, INTENSIVE SHRIMP PONDS

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	7.5	7.5
Effluent	Yes	2.5	2.5
Locations/habitats	Yes	2.5	2.5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	5	5
Feed	Yes	2.5	2.5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	2.5	2.5
Source of stock	Yes	10	10
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**37.5**

C1 Data Final Score	4.166666667	YELLOW

Criterion 2: Effluents

Factor 2.1a–Biological waste production score

Protein content of feed (%)	30
eFCR	1.42
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)	68.16
N in each ton of fish harvested (kg)	28.48
Waste N produced per ton of fish (kg)	**39.68**

Factor 2.1b–Production System discharge score

Basic production system score	0.51
Adjustment 1 (if applicable)	0
Adjustment 2 (if applicable)	0
Adjustment 3 (if applicable)	0
Discharge (Factor 2.1b) score	**0.51**

51 % of the waste produced by the fish is discharged from the farm

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?	Moderatel y	0.5
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?	No	0
3–Do the control measures address or relate to the cumulative impacts of multiple farms?	Moderatel y	0.5
4–Are the limits considered scientifically robust and set according to the ecological status of the receiving waterbody?	No	0
5–Do the control measures cover or prescribe including peak biomass, harvest, sludge disposal, cleaning etc.?	No	0
		1

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?	Partly	0.25
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
		0.25

F2.2 Score (2.2a*2.2b/2.5)	**0.1**

C2 Effluent Final Score	**4.00**	**YELLOW**
	Critical?	NO

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	4

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?	Partly	0.25
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?	Mostly	0.75
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)	Mostly	0.75
5–Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Moderately	0.5
		2.5

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?	Partly	0.25
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?	Partly	0.25
4–Is the enforcement process transparent–e.g., public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	No	0
5–Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Partly	0.25
		1

F3.2 Score (2.2a*2.2b/2.5)	1.00

C3 Habitat Final Score	3.00	RED
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score	
C4 Chemical Use Score	0	
C4 Chemical Use Final Score	**0**	RED
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Factor 5.1a–Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	24.13
Fishmeal from byproducts (%)	0
% FM	24.13
Fish oil inclusion level (%)	3.17
Fish oil from byproducts (%)	0
% FO	3.17
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.42
FIFO fishmeal	1.52
FIFO fish oil	0.90
Greater of the 2 FIFO scores	1.52
FIFO Score	**6.19**

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

SSWF	-6
SSWF Factor	-0.913722667

F5.1 Wild Fish Use Score	**5.28**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	30
eFCR	1.42
Feed protein from NON-EDIBLE sources (%)	0
Feed protein from EDIBLE CROP sources (%)	46.5

Protein OUTPUTS		
Protein content of whole harvested fish (%)		17.8
Edible yield of harvested fish (%)		67
Non-edible byproducts from harvested fish used for other food production		50
Protein IN		36.93
Protein OUT		14.863
Net protein gain or loss (%)		-59.7586
	Critical?	NO
F5.2 Net protein Score	**4.00**	

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 (%)	27.3
eFCR	1.42
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)	10.08

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

Inclusion level of crop feed ingredients (%)	72.7
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.42
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.39

Value (Ocean + Land Area)	**10.47**

F5.3 Feed Footprint Score	**6.00**

C5 Feed Final Score	**5.14**	**YELLOW**
	Critical?	**NO**

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	4

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	**4**

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?	Yes
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?	No
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	3.00	
C7 Disease; pathogen and parasite Final Score	**3.00**	**RED**
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	**-5.00**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	8.00	
C10Xb Biosecurity of source/destination	4.00	
C10X Escape of unintentionally introduced species Final Score	**-1.20**	**GREEN**