Environmental sustainability assessment of farmed Giant tiger prawn (*Penaeus monodon*) and Whiteleg shrimp (*Litopenaeus vannamei*) from Indonesia farmed using extensive ponds, intensive ponds, and semi-intensive ponds.

© Monterey Bay Aquarium

Species:	Giant tiger prawn (Penaeus monodon) Whiteleg shrimp (Litopenaeus vannamei)
Location:	Indonesia
Gear:	Extensive pond, Intensive pond, Semi-intensive pond
Type:	Farmed
Author:	Seafood Watch
Published:	May 5, 2025
Report ID:	977

Assessed using Seafood Watch Aquaculture Standard v4

Table of Contents

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 ratings 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 rating on the regional pocket guides is supported by a Seafood Watch Assessment. Each assessment 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 rating. This ethic is operationalized in the Seafood Watch standards, available on our website here. In producing the assessments, 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 ratings and the underlying assessments will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Watch assessments in any way they find useful.

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 farms must possess to be considered sustainable by the Seafood Watch program. Sustainable aquaculture farms and collective industries, by design, management and/or regulation, address the impacts of individual farms and the cumulative impacts of multiple farms at the local or regional scale by:

1. **Having robust and up-to-date information on production practices and their impacts available for analysis;**
   Poor data quality or availability limits the ability to understand and assess the environmental impacts of aquaculture production and subsequently for seafood purchasers to make informed choices. Robust and up-to-date information on production practices and their impacts should be available for analysis.
2. **Not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level;**
   Aquaculture farms 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.
3. **Being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats;**
   The siting of aquaculture farms does not result in the loss of critical ecosystem services at the local, regional, or ecosystem level.
4. **Limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms;**
   Aquaculture farms avoid the discharge of chemicals toxic to aquatic life or limit the type, frequency or total volume of use to ensure a low risk of impact to non-target organisms.
5. **Sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains;**
   Producing feeds and their constituent ingredients has complex global ecological impacts, and the efficiency of conversion can result in net food gains or dramatic net losses of nutrients. Aquaculture operations source only sustainable feed ingredients or those of low value for human consumption (e.g. by-products of other food production), and convert them efficiently and responsibly.
6. **Preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes;**
   Aquaculture farms, by limiting escapes or the nature of escapees, prevent competition, reductions in genetic fitness, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems that may result from the escape of native, non-native and/or genetically distinct farmed species.

---

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

7. **Preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites;**
   Aquaculture farms pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites, or the increased virulence of naturally occurring pathogens.
8. **Using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture;**
   Aquaculture farms use eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture, or where farm-raised broodstocks are not yet available, ensure that the harvest of wild broodstock does not have population-level impacts on affected species. Wild-caught juveniles may be used from passive inflow, or natural settlement.
9. **Preventing population-level impacts to predators or other species of wildlife attracted to farm sites;**
   Aquaculture operations use non-lethal exclusion devices or deterrents, prevent accidental mortality of wildlife, and use lethal control only as a last resort, thereby ensuring any mortalities do not have population-level impacts on affected species.
10. **Avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals;**
    Aquaculture farms avoid the international or trans-waterbody movements of live animals, or ensure that either the source or destination of movements is biosecure in order to avoid the introduction of unintended pathogens, parasites and invasive species to the natural environment.

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

Green: Buy first; they are well managed and caught or farmed in ways that cause little harm to habitats or other wildlife.

Yellow: Buy, but be aware that there are concerns with how they are caught or farmed.

Red: Do not buy; they are overfished or caught or farmed in ways that harm other marine life or the environment.

Final Seafood Rating

	L. vannamei			*P. monodon*
	Intensive	**Semi-Intensive**	**Extensive**	**Extensive**
Approximate annual production in 2022 (MT)	447,132	240,763	42,993	128,980
Criterion				
C1 Data	4.55	4.55	4.55	4.09
C2 Effluent	6.00	6.00	7.00	7.00
C3 Habitat	2.93	2.93	2.93	2.27
C4 Chemicals	3.00	3.00	6.00	6.00
C5 Feed	5.95	5.95	10.00	10.00
C6 Escapes	4.00	4.00	3.00	4.00
C7 Disease	4.00	4.00	6.00	6.00
C8X Source	0.00	0.00	0.00	–10.00
C9X Wildlife mortalities	–6.00	–6.00	–6.00	–6.00
C10X Introduction secondary species	0.00	0.00	0.00	–1.80
Total	24.43	24.43	33.48	21.56
Final score (0–10)	**3.49**	**3.49**	**4.78**	**3.08**

OVERALL RATING

	L. vannamei			*P. monodon*
	Intensive	**Semi-Intensive**	**Extensive**	**Extensive**
Final score	3.49	3.49	4.78	3.08
Initial rating	Yellow	Yellow	Yellow	Red
Red criteria	2	2	2	2
Interim rating	Red	Red	Red	Red
Critical criteria?	0	0	0	0
Final rating	**Red**	**Red**	**Red**	**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. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of –10 reflects a very significant impact. White text with a black background indicates a critical score. Two or more red criteria or one critical criterion result in a red final rating.

Summary

The final numerical scores for whiteleg shrimp (*L. vannamei*) produced in intensive, semi-intensive, and extensive production systems and for giant tiger prawn (*P. monodon*) produced in extensive production systems in Indonesia are 3.49, 3.49, 4.78, and 3.08 out of 10, respectively. But with multiple red criteria, the final rating is red for all scopes.

Executive Summary

In 2022, shrimp production in Indonesia totaled an estimated 898,984 metric tons (MT) (FAO, 2024). Whiteleg shrimp (*Litopenaeus vannamei*) accounted for approximately 80% (717,477 MT), followed by giant tiger prawn (*Penaeus monodon*) at 14% of production (126,121 MT). The remaining balance of approximately 5% mostly comprises various *Metapenaeus* spp. and *M. rosenbergii* (43,201 MT). This assessment is for the two dominant species: *L. vannamei* and *P. monodon.* The basic production system for both species is brackish-water ponds ("tambak" in Bahasa Indonesia), but the industry is quite diverse, with a range of farming practices across the complex geographical landscape of Indonesia. There are approximately 95,400 shrimp farms in Indonesia that comprise 497,506 ponds with a total area of 6,864 km^2 across 34 provinces. Roughly 93% of shrimp production by volume comes from the islands of Java (35%), Sumatra (21%), the Lesser Sunda Islands (22%), and Sulawesi (16%).

Determining the different types of pond production systems and associated farm practices utilized to produce *L. vannamei* and *P. monodon* in Indonesia is challenging, given the diversity of production systems and farm practices, yet it is important because of the associated distribution of potential ecological impacts. Based on the available information, and for the purposes of this assessment, it is estimated that 20% of Indonesia's shrimp farming production is produced from extensive systems, of which 5% is *L. vannamei* and 15% *P. monodon.* Semi-intensive and intensive systems grow *L. vannamei* only and represent 28% and 52% of the total shrimp production, respectively.

In 2021, total shrimp exports from Indonesia exceeded 250,000 MT,[2] showing a steady increase from approximately 130,000 MT in 2012. In 2022, Indonesia was the third largest supplier of shrimp to the United States (NOAA, 2022). According to U.S. National Oceanic Atmospheric Administration (NOAA) seafood database, shrimp exports from Indonesia to the United States in 2022 totaled roughly 166,922 MT, behind Ecuador (199,794 MT) and India (303,583 MT).

The purpose of this report is to assess the ecological impact of Indonesia shrimp production by species and production system and distill that to a rating. It should be noted that Seafood Watch has separate ratings for farmed shrimp certified to various assurance schemes. See the Seafood Watch information on certified seafood here.[3]

In this report, the evaluation of the ecological impact of shrimp farming involves multiple criteria that cover the impacts associated with effluent, habitats, wildlife mortalities, chemical use, feed production, escapes, introduction of secondary species (other than the farmed species), disease, the source of stock, and general data availability.[4] A summary of each criterion follows.

Criterion 1—Data

Given the technical and geographical complexity of the shrimp farming industry, it is perhaps inevitable that data availability and quality in Indonesia is fundamentally challenging. For a globally important shrimp aquaculture industry and an important source of exports to the U.S. seafood market, the readily

---

[2] Data from the Indonesian Department of Marine Affairs: https://statistik.kkp.go.id/home.php

[3] https://www.seafoodwatch.org/recommendations/certified-seafood

[4] The full Seafood Watch Aquaculture Standard is available at: https://www.seafoodwatch.org/recommendations/our-standards

available information is limited. As a result, describing and assessing the environmental impacts is challenging, and robustly identifying the risk and the burden associated with each species and production system across Indonesia is typically not possible (thus, some or all production systems and species must be grouped together for some criteria because of this inability to decouple impacts).

The most significant and effective information came from an in-country Seafood Watch Fellow, who organized a meeting with key stakeholders in September 2021 to gather information for this assessment. Feedback was recorded in the form of categorized notes and submitted documentation, and was followed up with additional targeted questions on the management, enforcement, practices, and impacts of shrimp farming. These discussions were updated with further stakeholder interviews in October 2023 and resulted in substantial information regarding regulations and management. Information on farm practices, production systems, biosecurity, and ecological impacts was also gathered from primary and grey literature, but significant gaps in the knowledge and robustness of data remain. For this Seafood Watch assessment, the limitations in data availability necessitate a precautionary approach to the scoring in many criteria.

Although there is some variability in data availability between production systems and species, the overall score for Criterion 1—Data is 4.55 out of 10 for extensive, semi-intensive, and intensive *L. vannamei*, and it is based largely on the available academic studies and the regulatory and management data submitted from stakeholders. For extensive *P. monodon*, the uncertainty regarding the sustainability of the *P. monodon* broodstock fishery results in a slightly lower score for Criterion 1—Data of 4.09 out of 10*.*

Criterion 2—Effluent

In unfed extensive *P. monodon* and *L. vannamei* shrimp farms, fertilizer application is the primary nutrient input that may pollute surrounding waterbodies if discharged in effluent. Although data are limited, it was estimated that 80 kg/ha of inorganic fertilizer (urea) is used, and with low shrimp yields per hectare (i.e., low nutrient outputs in harvested shrimp), the estimated net nitrogen in soluble and particulate waste is 39.95 kg N per MT of *P. monodon* and 41.71 kg N per MT of *L. vannamei* production in extensive systems. In fed *L. vannamei* semi-intensive and intensive systems, feed and fertilizer represent the primary nutrient inputs. For *L. vannamei* grown in intensive ponds (with an estimated feed protein content of 33.6%, an eFCR of 1.4, and urea fertilizer use of 0.6 kg N per MT of shrimp production), the resulting waste production is 47.38 kg N per ton of *L. vannamei.* In semi-intensive systems (with an estimated feed protein content of 33.6%, an eFCR of 1.4, and fertilizer use of 2.58 kg N per MT of shrimp production), the resulting waste production is 49.36 kg N per ton of *L. vannamei.* Considering the nutrient dynamics in ponds as well as the typical water exchange rates, water treatment, and the collection and appropriate disposal of sludge (although these vary between production systems), 18% of the waste N produced is considered to be discharged from extensive systems, resulting in a score for Factor 2.1—waste discharge of 9 out of 10 for extensive systems growing *L. vannamei* and *P. monodon.* For semi-intensive and intensive systems growing *L. vannemei,* 27% of the waste N produced is considered to be discharged, resulting in a score of 8 out of 10.

Indonesia has a new legislative framework for natural resource management, which covers shrimp farming, and it is intended to be an area-based, cumulative management system. There are also provincial/sub-national spatial management plans, which set a goal of an area-based, cumulative management framework. But the necessary integration of aquaculture with other socioeconomic industries appears to be lacking. Wastewater treatment and water quality standards are additional core ecological principles to regulate and limit effluent pollution within the carrying capacity of receiving waters; however, despite updated water quality discharge limits for shrimp farms, there is no readily available evidence to suggest that these limits are prescriptive to the various waterways, locations, and ecosystems into which shrimp farms discharge effluent in Indonesia. There are new requirements for sedimentation ponds, which may help to reduce the evidence of coastal degradation (for which shrimp aquaculture wastewater is a significant source), but their implementation appears lacking. Overall, the management system does appear to set effluent discharge limits, but there is no evidence to suggest that they are set to minimize area-based or cumulative-level impacts. The score for Factor 2.2a—content of regulations is a moderate 3 out of 5.

Enforcement of effluent management measures appears to be limited. The agencies enforcing effluent limits are active, but they may have limitations in resources. The intended frequency of farm visits depends on the size of the farm and the compliance history. Data demonstrating enforcement of these inspections are lacking, and the inconsistency of inspections and the lack of an identifiable strategy limit the potential enforcement effectiveness. There is considered to be area-level monitoring of waterbodies, but the adaptive management and enforcement principles—such as feedback loops between monitoring noncompliance at the area level and enforcement "upstream" to point or nonpoint sources of shrimp farms—appear to be missing. Importantly, public evidence of compliance and monitoring data is not mandatory, is published inconsistently, and is apparently not readily available. As a result, enforcement measures and monitoring and compliance data are considered limited. The score for Factor 2.2b—enforcement of regulations is 2 out of 5 and is applied to all species and systems.

Combining all factors results in the following Criterion 2—Effluent scores:

- *L. vannamei* intensive, 6 out of 10
- *L. vannamei* semi-intensive, 6 out of 10
- *P. monodon* extensive, 7 out of 10
- *L. vannamei* extensive, 7 out of 10.

Criterion 3—Habitat

The conversion of mangroves or wetlands to aquaculture ponds is considered to result in a loss of the important ecosystem services typically associated with those habitat types. Nearly 1 million hectares, or 22%, of Indonesia's total mangrove forest area were deforested from 1800 to 2012, and for major shrimp-producing islands, nearly half of their historical total mangroves have been lost (about 49% or 1.3 million hectares total from 1800 to 2022, or 73% loss on Java, 54% on Sulawesi, 39% on Kalimantan, and 30% on Sumatra). Noting that there is some uncertainty in the scale of shrimp farming's role in this long-term mangrove land use change, the general literature does indicate that the mangrove forests of these islands have been majorly affected by their conversion to shrimp farms. By comparing the total shrimp pond area in 1999 and 2022, it appears (with some exceptions) that roughly two-thirds of the pond area present in 2022 was developed before 1999—an important baseline for this assessment. The most recent data available (2020–22) indicate that there is still ongoing conversion of mangroves within each of the significant shrimp farming areas—Kalimantan, Java, Sulawesi, and Sumatra—although the most recent data show that the rate of conversion between 2020 and 2022 has declined for all regions. Altogether, there is a complex pattern of habitat conversion across the islands, the species farmed, and timeframes, but by considering the characteristics of each island group and the dominant species produced, some distinctions can be made:

- The typical or average shrimp farm in Kalimantan is considered to have been built in high-value habitats such as mangroves or wetlands relatively recently (after 1999), and there is evidence of recent or ongoing conversion. The score for Factor 3.1—habitat conversion and function for

Kalimantan is 0 out of 10. Harvest data indicate that nearly one-third of Indonesia's *P. monodon* is produced on Kalimantan, with no significant *L. vannamei* production.

- For the other islands, the typical or average shrimp farm is also considered, on a precautionary basis, to have been built in high-value habitats, but mostly before 1999 (Java, 98%; Sulawesi, 85%; Sumatra, 90%; and the Lesser Sunda Islands, 90%). The score for these islands is 4 out of 10. The island harvest figures indicate that both species are produced to varying degrees on these islands, but *L. vannamei* is dominant.

By considering the different species' production characteristics across the main island groups, a weighted score for Factor 3.1 for each species can be determined that more closely reflects the associated habitat conversions across Indonesia. As a result, the weighted island/species scores across Indonesia for Factor 3.1 are 3 out of 10 for *P. monodon* and 4 out of 10 for *L. vannamei*.

Current habitat management measures that define the recent and ongoing development of shrimp farming in Indonesia are based on ecological principles, yet appear to be limited in their implementation. It is up to each province—and the respective regional planning agency (BAPPEDA)—to develop a detailed development plan, with resource use zones determined by an ecosystem's carrying capacity as reflected in the RZWP3K—Zoning Plan for Coastal Areas and Small Islands. But even though aquaculture zones have been defined, there is no readily available information demonstrating that an effective carrying-capacity study has been defined or implemented (i.e., supportive regulation/guidance). Without a transparent and justified spatial management plan, important management principles such as cumulative impacts and habitat connectivity do not appear to be incorporated. Farm siting within aquaculture zones requires a permit and/or license, for which the associated environmental review and its rigor is dependent on the size of the planned farm, but it is unclear what habitat protections are mandated through this process (if any) for any size of farm. Presidential Decrees No. 32 of 1990 and No. 51 of 2016 state that aquaculture farms cannot be sited within a green belt (100 m from the coast and 50 m from inland waterways), in order to create a buffer for mangrove forests, but evidence suggests that they are not effectively enforced in the farm siting process. There have been substantial conservation efforts to protect and replant mangroves in Indonesia, which have had some success, but they have fallen short of lofty goals and expectations. Overall, the content of the habitat management framework is considered to lack a clear demonstration of the practical measures necessary to effectively achieve the ecological principles underpinning sustainable aquaculture, carrying capacity, and cumulative management. As a result, the content of habitat management measures is limited, and Factor 3.2a scores 2 out of 5.

There are numerous national and provincial agencies charged with managing shrimp farm siting and mangrove protections, but there is a clear pattern (as detailed in Factor 3.1) of ongoing land-use change of mangroves to brackish-water ponds on every island where there is significant pond area. The siting of shrimp farms in aquaculture zones and outside mangrove greenbelts is enforced through permit applications and field audit visits, but compliance rates are unknown, and there is some evidence to suggest that enforcement of these regulations is minimal (one report of illegal clearance and encroachment of mangrove forests was found, but it is not known if this is an isolated occurrence). The ongoing conversion may be due to differing scopes of management agencies and national goals, which creates challenges for the government to enforce mangrove protections and farm siting effectively and consistently across Indonesia. Restoration remains an ongoing priority, with some success. Altogether, it appears that enforcement organization and their activities are difficult to identify, with little evidence of monitoring or compliance data and limited evidence of penalties for infringements. As a result, the Factor 3.2b score is 1 out of 5. Therefore, the overall effectiveness of the management system (for all production systems) is considered to be limited, and the score for Factor 3.2 (combining Factors 3.2a and 3.2b) is 0.8 out of 10.

Combining Factors 3.1 and 3.2 results in the following scores for Criterion 3—Habitat:

- *L. vannamei* intensive is 2.93 out of 10
- *L. vannamei* semi-intensive is 2.93 out of 10
- *L. vannamei* extensive is 2.93 out of 10
- *P. monodon* extensive is 2.27 out of 10.

Criterion 4—Chemical Use

There is limited published and verifiable information available from the government, industry, or literature detailing the current chemical use (or lack thereof) by shrimp farms in Indonesia. What is known about pond preparation chemicals (such as lime), disinfectants, and piscicides indicates that their use is a relatively low concern. In contrast, the lack of detailed, publicly available information regarding the types and quantities of antimicrobial usage thus limits the potential analysis of this criterion and (along with global concerns regarding the overuse of antimicrobials) drives a precautionary approach for this group of chemicals. Therefore, antimicrobials are the focus of this assessment.

Under the Ministerial Regulation on Fish Medicine (No.1-2019), Indonesia permits six antimicrobials for aquaculture, of which four are classified as highly important for human medicine by the World Health Organisation (WHO) and two are classified as critically important. Although some restrictions on the use of these antimicrobials are in place (for example, requirements for a veterinary prescription), there do not appear to be any regulatory limits on the frequency of use or on their total use. The lack of publicly available information documenting antimicrobial usage (e.g., total use, frequency, type, distribution, and sales) also obscures any objective measures to understand enforcement effectiveness. In addition, academic literature, though limited, indicates a limited enforcement of broader antimicrobial policies across several industries in Indonesia (including aquaculture). There are many studies that highlight the potential risk of antimicrobial usage in the environment, and numerous studies detect antimicrobial residues and bacterial resistance to (sometimes multiple) antimicrobials in shrimp or shrimp ponds in Indonesia. These include antimicrobials classified as highly important and critically important to human medicine by WHO, and one prohibited in Indonesia (chloramphenicol). Yet there is no readily available information that clearly implicates antimicrobial usage on shrimp farms in these findings. In contrast, there are indications that some sectors of the shrimp farming industry use no antimicrobials (especially for *P. monodon*), but the lack of robust data again confounds solid conclusions in this regard.

Overall, the lack of information means that the chemical use characteristics of shrimp farms in Indonesia are effectively unknown. Some regulatory limits are in place, primarily restricting the types of treatments permitted, but the enforcement effectiveness is unclear. Other governance mechanisms, such as extension guidance for antibiotic-free disease management (see Criterion 7—Disease) and processors refusing shrimp that test positive for antibiotic residues, appear to be fairly effective, and there have been no import refusals for antibiotic residues since 2018. Nonetheless, antibiotics are still detected in and around shrimp farms, and shrimp farms and their products are associated with various aspects of antimicrobial resistance, including resistance associated with antimicrobials that are important for human health. Therefore, while there are some management measures with demonstrated effective enforcement that limit the use of chemicals (a score of 4 out of 10), there is also evidence in the literature of chemical use on shrimp farms that discharge into the environment, and data concerning the use of chemicals are unavailable (a score of 2 out of 10). The available information generates a precautionarily high level of concern, and *L. vannamei* grown in both semi-intensive and intensive production systems score an intermediate 3 out of 10 for Criterion 4—Chemical Use. Although data are also limited for *P. monodon* and *L. vannamei* extensive farms, they have low stocking densities with large pond areas and little input, and according to government regulators, *P. monodon* does not use any chemical inputs. Although it is not assumed that these farms are entirely chemical free, they are considered to have a low need for chemical use; therefore, the final scores for both extensive *P. monodon* and *L. vannamei* are 6 out of 10 for Criterion 4—Chemical Use.

Criterion 5—Feed

There are some indications that feed may occasionally be used in extensive *P. monodon* and *L. vannamei* production, but overall, it is assumed to be insignificant for the purposes of this assessment. Therefore, the final scores for Criterion 5—Feed for *P. monodon* and *L. vannamei* in extensive systems are 10 out of 10.

For *L. vannamei* in fed semi-intensive and intensive systems, a variety of sources of feed information were used, including from farming companies, feed mills, certified farms, and academic literature. Nevertheless, information differentiating the specific feed characteristics of the two systems (e.g., eFCR, protein content, and ingredients) was not robustly available. Therefore, the assessment was completed for *L. vannamei* independent of the production system, and the score applies to both semi-intensive and intensive production.

Using the available data, *L. vannamei* grown in intensive and semi-intensive production systems are calculated to have a forage fish efficiency ratio (FFER) of 0.31. This means that, from first principles, 0.31 MT of wild fish would need to be caught to produce 1.0 MT of farmed shrimp. Data describing marine ingredient sources were limited, but some information, though missing key insights such as the fishing method and fishing location (e.g., FAO region), was made available to allow for a limited source fishery sustainability evaluation. The fishmeal and fish oil marine ingredients were derived from by-products (e.g., skipjack tuna, yellowfin tuna, and farmed Chilean Atlantic salmon) and whole fish (sardine and anchovies), resulting in a score for Factor 5.1b—source fishery sustainability of 6 out of 10. The scores for Factor 5.1a (0.31) and Factor 5.1b (6 out of 10) combine to give Factor 5.1—wild fish use scores of 7 out of 10 for *L. vannamei* in both intensive and semi-intensive systems.

With an estimated average feed protein content of 33.6% for *L. vannamei* in intensive and semi-intensive systems, there is a substantial net protein loss of 62.2%, which results in a score for Factor 5.2—net protein gain or loss of 3 out of 10. The feed footprint (Factor 5.3) was estimated as 1,825.45 kg CO_2-eq per MT of shrimp feed , which is driven by the substantial inclusion of soybean meal. Considering a whole-harvest shrimp protein content of 17.8% for *L. vannamei* and an eFCR of 1.4, it is estimated that the feed-related GWP of 1 kg of semi-intensive and intensive farmed *L. vannamei* protein is 14.34 kg CO_2-eq. This results in a score of 6 out of 10 for Factor 5.3.

Combined, the final score for Criterion 5—Feed for *L. vannamei* in both semi-intensive and intensive production systems is 5.95 out of 10. (See the Seafood Watch Aquaculture Standard for full details of the scoring calculations.)

Criterion 6—Escapes

For *L. vannamei* on intensive and semi-intensive farms, the escape risk that is associated with flooding (i.e., farm location) and the daily exchange rate (3–10%) is considered to be slightly lower than that for extensive farms, but is still high, and the score for Factor 6.1—Escape Risk is 3 out of 10. The escape risk of *L. vannamei* on extensive production systems is considered to be high, because they rely on tidal water exchanges and must be located in areas that are considered at high risk of flooding. As a result, Factor 6.1—Escape Risk scores 0 out of 10 for extensive systems.

A review of literature surrounding competitive and genetic interactions of escape farmed shrimp with wild species revealed that there is no evidence of nonnative *L. vannamei* establishing viable populations anywhere in the world, and it is concluded that, although *L. vannamei* is likely to be present in the wild in Indonesia, it is not considered to be established and is highly unlikely to establish viable populations. Thus, the score for Factor 6.2—Competitive and Genetic Interactions for *L. vannamei* is 6 out of 10. Combined, the final score for Criterion 6—Escapes for *L. vannamei* intensive and semi-intensive production systems is 4 out of 10. With a higher risk of escape, *L. vannamei* grown in extensive systems has a final Criterion 6—Escapes score of 3 out of 10.

Because *P. monodon* on farms originates from wild-caught broodstock, in the event of an escape, it is unlikely to present significant competitive or genetic risks to wild populations, given its native status and high genetic similarity to wild conspecifics. The score for Factor 6.2—Competitive and Genetic Interactions is 8 out of 10. Combined, the score for Criterion 6—Escapes for *P. monodon* in extensive production systems is 4 out of 10.

Criterion 7—Disease

Data describing disease severity and frequency by species and or production system are limited (so the risk-based assessment is used), but the general literature indicates that shrimp farming in Indonesia is significantly affected by disease. For example, in 2018, it was estimated that the combined economic losses due to shrimp diseases in Indonesia was about USD295 million (which was 74% of Indonesia's total aquaculture economic loss from disease in all farmed species). In 2020, the average annual industry mortality rate was 50%, and more recent data indicate a high variability in survival/mortality rates across production systems, seasons, and cycles (for which disease is one of many factors). A recent study reported that nearly half of all farms sampled (n = 120) experienced at least one disease issue per cycle, with the most frequent disease occurrences being AHPND ≈25%, EHP ≈5%, and WSD ≈11%, which can drastically reduce survival rates to potentially less than 10% in the worst cases.

Regulations and government agencies are focused on prevention, control, industry guidelines, and coordination among farms at the area level and at the farm level, to limit the spread of disease. This has resulted in monitoring, surveillance, testing, and government-led trainings on biosecurity (i.e., identification of disease symptoms, detection, control of pathogens, best management practices, disease eradication, and disinfection). This indicates that there are some biosecurity measures and/or protocols in place, but there are apparent limitations in their effectiveness, given the severity of disease-related issues seen on farms.

Evidence of disease transmission from farms to wild species is limited, and further research is needed because the risk of impacts to wild populations (compared to those in farms) from pathogens commonly found in shrimp farms remains uncertain. The variable host ranges of many pathogens mean that there is no robust reason to distinguish the two farmed shrimp species here regarding their risk of disease transmission to wild species.

Therefore, the score for Criterion 7—Disease is a combination of conditions, with scores differing by production system. Without further details readily available, it is assumed that semi-intensive and intensive production systems bear the burden of the noted high disease-related or pathogen-related mortalities that hamper the industry. This is because of the higher intensities (e.g., feed use, stocking density) of these systems and because the majority of production stems from semi-intensive and intensive production systems. There are government-led regulations, certifications, and interventions, so there appears to be some level of biosecurity measures in place across the industry; however, all production systems are still open to the introduction of pathogens and parasites and to the discharge of pathogens, especially considering the average daily exchange rate of > 3% of untreated water. This results in a score of 4 out of 10 for Criterion 7—Disease for intensive and semi-intensive production systems.

Extensive production systems are associated with production practices that do not increase the likelihood of pathogen amplification compared to natural populations (there is no feed applied, and the stocking density is low: less than 10 post-larvae per m^2) (score of 8). The reportedly low survival rates (20–40%) for *L. vannamei* and *P. monodon* grown extensively are the result of high predation within these systems and the limited availability of feed/increased competition for resources—not primarily disease. Because these systems are also within the industry-wide biosecurity governance and have a high exchange rate with no treatment of discharge (score of 4), an intermediate score is warranted and results in a score of a 6 out of 10 for Criterion 7—Disease for extensive production systems.

Criterion 8X—Source of Stock

Nearly all black tiger shrimp broodstock are sourced from the wild, and the status of the wild *P. monodon* stock is considered to be overexploited, so the score for *P. monodon* in Criterion 8X is –10 out of –10. For *L. vannamei*, there is no use of wild-caught broodstock (or PL), so the final score for Criterion 8X is a deduction of 0 out of –10.

Criterion 9X—Wildlife Mortalities

There is little information and there are few data available on the interactions and/or potential mortalities of wildlife on shrimp farms in Indonesia. From a regulatory perspective, the Indonesian Act on the conservation of biological resources and their ecosystems (Act No. 5 of 1990) and Regulation No. 20/MENLHK/SETJEN/KUM.1/6/2018 are the major legislative frameworks intended to protect more vulnerable species from any lethal control; however, enforcement is reportedly limited. Regulatory measures or management guidance for other species (i.e., those not necessarily in danger of extinction) were not readily available. Indonesia is a biodiversity center, and aquaculture is associated with threats to 186 species, according to the International Union for the Conservation of Nature (IUCN); however, it is unclear how many of these species, if any, are affected by daily operations of the farms (as opposed to habitat loss or alteration during farm construction). Many of the animals known to interact with farms (e.g., lizards, turtles, snakes, birds, crustaceans, finfish, cats, dogs, goats, and boar) can be deterred or excluded by simple fences, barriers, or netting, and shrimp farms are generally known to use them. There is limited evidence to suggest that any lethal controls are used, although the use of piscicides or crustacides (i.e., saponin, crustacide, and/or nuvet) in influent waters may be common to kill fish or crustacea that may be pathogen carriers or predators. Overall, given the significant biodiversity of Indonesia and the limited readily available information or data regarding wildlife interactions or mortalities, the risk assessment must be used on a precautionary basis. Therefore, although there are known regulatory measures in place that aim to limit wildlife mortalities, enforcement is reportedly weak and there are no data available on interactions or mortalities. The final score for Criterion 9X—Wildlife Mortalities is –6 out of –10.

Criterion 10—Introduction of Secondary Species
Production of *L. vannamei* in Indonesia relies entirely on the trans-waterbody movements of live shrimp: either from international breeding centers (as adult broodstock or post-larvae) to hatcheries or broodstock multiplication centers (BMC) in Indonesia, or of adult broodstock from BMCs and domestic breeding programs to hatcheries across Indonesia. The subsequent movements of post-larvae from hatcheries to relatively local grow-out ponds are not considered here. The score for Factor 10Xa is 0 out of 10. With high biosecurity of the sources, and moderate biosecurity at the destination hatcheries, the score for Factor 10Xb is 10 out of 10. Thus, the combined final score for Criterion 10X for *L. vannamei* is a deduction of 0 out of –10.

Production of *P. monodon* depends largely on the movements of wild-caught broodstock (considered to be landed in Aceh in Sumatra) to hatcheries across Indonesia. With 90% of production considered dependent on these movements (i.e., all production outside Sumatra), the score for Factor 10Xa is 0 out of 10. Given the open nature of the wild fisheries for *P. monodon*, it is challenging to prevent a secondary species from being unintentionally transported with broodstock movements across Indonesia, despite the biosecurity measures in place. But it appears that the destination hatcheries (and the quarantine controls along the supply chain from port to hatchery) implement several biosecurity controls and quarantine procedures (i.e., zero exchange tank quarantine upon arrival to hatcheries and PCR tests) that limit the potential risk of an unintentionally transported secondary species escaping into a new environment. The score for Factor 10Xb is decided by the higher score of either the source or the destination of movements (i.e., high biosecurity at either the source or the destination of movements can prevent the escape of a secondary species into the environment). Therefore, the score for *P.* monodon is based on the high biosecurity at the destination hatcheries and is 8 out of 10. The combined final score for Criterion 10X for *P. monodon* is a deduction of –1.8 out of –10.

Final Scores and Ratings:
The final scores and Seafood Watch ratings are summarized as follows:

- The final numerical score for *L. vannamei* produced in intensive pond systems in Indonesia is 3.49 out of 10, which is in the yellow range, and with two red criteria, the final rating is red.
- The final numerical score for *L. vannamei* produced in semi-intensive pond systems in Indonesia is 3.49 out of 10, which is in the yellow range, and with two red criteria, the final rating is red.
- The final numerical score for *L. vannamei* produced in extensive pond systems in Indonesia is 4.78 out of 10, which is in the yellow range; however, with two red criteria (Habitat and Escapes), the final rating is red.
- The final numerical score for *P. monodon* produced in extensive pond systems in Indonesia is 3.08 out of 10, which is in the red range, and with two red criteria, the final rating is red.

Scope of the analysis and ensuing rating

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

Geographic Coverage
Indonesia

Production Method(s)
Intensive ponds (*L. vannamei*)
Semi-intensive ponds (*L. vannamei*)
Extensive ponds (*P. monodon*)
Extensive ponds (*L. vannamei*)

Species Overview

Brief Overview of the Species

As noted in the following production statistics, two species dominate shrimp farming in Indonesia: the native giant tiger prawn (*P. monodon*) and the introduced (nonnative) whiteleg shrimp (*L. vannamei*). *P. monodon* is indigenous to Indonesia, with a native geographic range that includes the coasts of Australia, Asia, Southeast Asia, and Eastern Africa (FAO, 2005–2023). 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 200 to 320 g (FAO, 2005–2023). *P. monodon* is found only in tropical marine habitats, and though it spends the majority of its life in shallow estuaries, lagoons, or mangrove areas, adults can often be found at depths of 20–50 m in offshore waters (FAO, 2005–2023). *L. vannamei* grows to a smaller overall size than *P. monodon*, reaching a maximum length of 23 cm (9 in) and is translucent white with changes in pigmentation varying by substratum, feed composition, and water turbidity (FAO, 2005–2023). *L. vannamei* is naturally found along the tropical Pacific coast of Central and South America from northern Mexico to northern Peru (Briggs et al. 2004), and was officially approved for shrimp farming in Indonesia in 2001 (Briggs et al. 2005) (Sugama 2006) (Taukhid and Nur'aini 2009) (Yi et al. 2009).

Industry Statistics and Production Methods

According to the FAO (FishstatJ database), shrimp and prawn production in Indonesia totaled 898,984 metric tons (MT) in 2022, which is a decrease of 53,856 MT from the previous year. The top species farmed in Indonesia are summarized in Table 1. Further data differentiating the total production area by production system type and location, as well as volume by location and species, were derived from the Indonesian government[5] (see Tables 2 and 3), which largely aligns with FAO's reported production volume totals for each species.

---

[5] https://statistik.kkp.go.id/home.php

Table 1: Indonesia shrimp production by species in metric tons, excluding decimal values. Source: FAO, 2024.

Species	2014	2015	2016	2017	2018	2019	2020	2021	2022
L. vannamei	428,905	406,795	476,455	737,029	685,730	664,750	696,570	768,785	702,345
P. monodon	129,231	125,073	128,655	126,191	159,980	133,187	133,237	133,676	126,077
M. rosenbergii	1,809	832	17,936	1,800	3,869	5,829	877	988	5,812
Metapenaeus shrimps nei	11,031	42,303	43,906	29,503	22,622	40,120	49,530	36,162	37,388

Species

In 2022, whiteleg shrimp (*L. vannamei*) accounted for ≈80% (717,477 MT) of total shrimp production, followed by giant tiger prawn (*Penaeus monodon*) at 14% of production (126,121 MT). The remaining balance of ≈5% mostly comprises various *Metapenaeus* spp. and *M. rosenbergii* (43,201 MT) (Table 1).

Production dramatically shifted from primarily *P. monodon* to *L. vannamei* in the mid-2000s. This shift took place throughout South and Southeast Asian shrimp production areas, because *L. vannamei* performs better in captivity, is tolerant of a wider range of salinities, and exhibits better growth performance than *P. monodon* (Amelia et al., 2021).

Production System

There are about 95,400 shrimp farms that comprise 497,506 shrimp ponds across 34 provinces in Indonesia (pers comm. 2021, *Aquascape Longline Environment*). Determining the different types or intensities of pond production systems and the associated farm practices utilized to produce *L. vannamei* and *P. monodon* in Indonesia is challenging, given the diversity of the industry, the number of farms, and the geographic spread, yet it is important because of the associated distribution of ecological impacts across various contexts. This section seeks to define the different types and practices of production systems utilized for shrimp farming in Indonesia, to establish the applicable scope of this assessment.

In general, there are extensive, semi-intensive, and intensive shrimp farming production systems operating in Indonesia (Indonesian government's data portal, Statistik-KKP[6]) (Indonesia Shrimp Forum, 2019) (Sari, I., 2015 citing MMAF 2006) (Poernomo 1989) (Sianipar & Genisa 1987) (Suyanto & Mujiman 1995) (Zainun et al. 2007). These systems are typically differentiated by the stocking density and the amount of inputs and technology utilized, like feed and aeration (Sari, I., 2015 citing Apud 1985) (Kungvankij 1985) (Shang, Leung & Ling 1998). A summary follows of each production system type and associated production metrics (expressed as a percentage).

Estimating Production Volume by Production System

To determine the percentage of volume associated with each production system type, some assumptions and analyses were made. Statistics describing the total area of pond production by production system type (i.e., extensive, semi-intensive, and intensive) and province were available from Indonesia's Statistik-KKP data portal.[7] The total pond area by island is summarized in Table 2.

---

[6] https://statistik.kkp.go.id/home.php

[7] https://statistik.kkp.go.id/home.php?m=luaslahan&i=7#panel-footer-kpda

Table 2: Pond area in hectares by pond type and island in 2021 and 2022. Source: Statistik-KKP.

Island	Extensive		Intensive		Semi-intensive	
	2021	2022	2021	2022	2021	2022
Java	105,967	102,282	5,607	5,455	9,809	10,123
Kalimantan	253,041	254,282	89	91	41	2
Sulawesi	163,868	324,146	1,243	1,057	10,316	4,806
Sumatra	48,662	62,118	28,256	14,646	29,731	31,292
Lesser Sunda Islands	4,101	4,654	3,932	4,314	898	2,172
Maluku	113	392	353	354	5	1
Riau Archipelago	35	2	18	72	43	10
Papua	76	76	—	—	67	67
Total	575,863	747,952	39,535	26,013	50,911	48,479

To estimate the production volume by production system type and by island, an estimate of the productivity of each system type was multiplied by the total area of each production system type. Results were then compared to production volume totals by island and species from Indonesia's Statistik-KKP data portal[8] (see Tables 3 and 4) to help guide the productivity and resulting volume estimates. Annual productivity (yield) estimates were derived from the literature for extensive,[9] semi-intensive,[10] and intensive[11] systems, and were reportedly about 1.51 MT/ha/year, 7 MT/ha/yr, and 30 MT/ha/yr, respectively. But using these values resulted in a high overestimate of production volume

Table 3: Reported production volume in metric tons of *P. monodon* and *L. vannamei* by island for 2021 and 2022. Source: Statistik-KKP.

Island	*P. monodon*		*L. vannamei*	
	2021	2022	2021	2022
Java	41,945	40,630	292,843	257,159
Kalimantan	33,516	34,392	1,734	1,166
Sulawesi	23,193	21,273	123,070	116,743
Sumatra	34,894	32,081	160,573	148,699
Lesser Sunda Islands	46	126	177,496	186,042
Maluku	0	34	9,444	10,194
Riau Archipelago	0	0	1,182	3,073
Papua	82	82		
Total	133,676	128,618	768,837	731,252

---

[8] https://statistik.kkp.go.id/home.php?m=prod_ikan_prov&i=2#panel-footer-kpda

[9] Productivity for extensive systems was estimated as < 5 MT per hectare per year (Anonymous, 2021), while Boyd et al. (2021a) estimated pond yields of 1.51 MT/ha/year, and 1.51 is used.

[10] Semi-intensive production systems range from 5 to 30 MT/ha/year (Sari, I., 2015, citing Zainun et al. 2007), while more recent estimates are 7 MT/ha/year (pers comm Budhi Wibowo, citing Indonesia Shrimp Forum, 2019).

[11] Productivity estimate is > 30 MT/ha/year and the lower end is used (MMAF, 2021) (pers comm Budhi Wibowo, 2023, citing Indonesia Shrimp Forum, 2019) (Halim, D. 2016, citing Ministry of Maritime Affairs and Fisheries).

Table 2: Estimate of production volume (metric tons) by pond type and island in 2022 and reported volume in 2022. Source: Statistik-KKP.

Island	Reported 2022 Total	Extensive	Semi-Intensive	Intensive	Estimated 2022 Total	Difference between Estimated and Reported
Java	297,789	14,303	50,617	109,096	174,016	(123,773)
Kalimantan	35,558	35,558	10	1,828	37,396	1,838
Sulawesi	138,016	45,328	24,032	21,136	90,496	(47,520)
Sumatra	180,780	8,686	156,462	292,918	458,067	277,287
Lesser Sunda Islands	186,168	651	10,860	86,272	97,783	(88,385)
Maluku	10,228	55	6	7,089	7,150	(3,078)
Riau Archipelago	3,073	0	52	1,441	1,494	(1,579)
Papua	82	11	334	—	345	263
Total	859,870	104,591	242,375	519,781	866,747	6,877

compared to reported volumes, so semi-intensive and intensive productivity were slightly reduced to 5 MT/ha/yr and 20 MT/ha/yr, respectively. Extensive productivity was estimated by dividing the total volume in 2022 of Kalimantan (*L. vannamei* and *P. monodon*) by the extensive pond area of Kalimantan (the extensive area is nearly 99.9% of the Kalimantan production area). This resulted in an estimate of 0.14 MT/ha/yr of extensive production, which corroborates with the literature of < 1 MT/ha. Altogether,using the productivity estimates for this calculation resulted in a close alignment with reported volume totals (Table 4).

To help further refine the production volume estimates by production system type, the reported percentage of production volume for each production system type is the result of combining two estimate sources. The production volume by production system type derived from the previous methods is expressed as a percentage and is averaged with the Indonesia Shrimp Forum's prediction of production by system type in 2019[12] (figures provided by pers comm, Wibowo, ISF, September 2023). It should be noted that it is unclear how ISF categorizes and differentiates the production system types. The two sources were combined to help even out the reported differences in estimated production—particularly the difference of extensive (12–29%) and intensive (44–60%) pond systems. Results are reported in the following paragraphs, while the total volume is reported in Table 5.

The following percentage estimates refer only to *L. vannamei* and *P. monodon*, which are within the scope of this assessment (i.e., the two minor species in Table 1 are not included, so the total of *L. vannamei* and *P. monodon* equals 100% but accounts for ≈95% of shrimp production in Indonesia).

Extensive: 20% of total shrimp production/≈25% L. vannamei *and ≈75%* P. monodon
As a result of the methods described, extensive systems are estimated to account for ≈20% of Indonesian shrimp production. *P. monodon* is the primary species farmed in extensive systems in Indonesia (pers comm, Dr. Bambang Widigo and Mr. Budi Wibowo, 2023) (Sari, I., 2015, citing Yi et al.

---

[12] The estimate as a percentage of total volume in 2022 is 12% Extensive, 28% Semi-Intensive, 60% Intensive, where the Indonesia Shrimp Forum estimates were: 29% Extensive, 27% Semi-Intensive, 44% Intensive.

Table 3: Estimate of volume (metric tons) by species and production system type for all of Indonesia in 2022.

Production System Type	Estimated Total Production (%)	Total Volume (MT)	Estimated Volume (MT)	Percentage of *P. monodon*	Percentage of *L. vannamei*	Estimated Volume in 2022	
						P. monodon **(MT)**	***L. vannamei*** **(MT)**
Intensive	52%	859,870	447,132.40	0%	100%	0	447,132
Semi-Intensive	28%		240,763.60	0%	100%	0	240,763
Extensive	20%		171,974.00	75%	25%	128,980	42,993
					Total	**128,980**	**730,890**

2009), but farms may cultivate more than one species in the pond at a time (polyculture); for example, with milkfish and/or with *L. vannamei* (pers comm, FUI, 2024). There does appear to be significant production of *L. vannamei* in extensive production systems in Indonesia as well. The Indonesia Shrimp Forum (2019) estimated ≈15% of total shrimp production is of *P. monodon* from extensive systems (which aligns with the FAO estimate of 15%), while about 5% is *L. vannamei* from extensive systems.

Typical attributes of extensive shrimp farming include no lining of pond bottoms, minimal inputs including feed, reliance on plankton or other natural food production, and they may be integrated with mangroves (often referred to as silvoculture or silviculture) (pers comm, AP5I—Indonesia Fishery Producers Processing and Marketing Association, Shrimp Club of Indonesia, and the Forum Udang Indonesia—Indonesian Shrimp Forum) (Amelia et al., 2021). Typically, the stocking density is < 10 post-larvae (PL) per square meter, and an average pond size between 1 and 10 ha (pers comm, Pratiwi, 2021) (pers comm, Wibowo, 2023). It is estimated that the average yield for extensive farms is < 5 MT per hectare per year (Anonymous, 2021), while Boyd et al. (2021a) estimated pond yields of 1.51 MT/ha/year. Water typically flows from a canal and into the production pond through tidal exchange entering through an inlet point—a water gate—that acts as a dam, controls the water level, and is the outlet point (pers comm, Pratiwi, 2021) (Sari, I., 2015). Extensive farmers rely upon the highest monthly tides to replenish pond water lost to evaporation (pers comm, Saenong, 2025). The resulting average daily water exchange rate is estimated to be less than 3% (pers comm, Saenong, 2025). There is typically no wastewater treatment pond or reservoir. Production cycles are about 4–8 months per cycle, and use hatchery-sourced post-larvae (Sari, I., 2015, citing Zainun et al. 2007) (Yi et al. 2009). Figure 1 shows an example layout of an extensive pond in West Java, Indonesia.

The term "extensive farming" or traditional farming encompasses a range of practices, including silvoculture, polyculture, semi-extensive (or "traditional plus," which involves minimal supplemental feed inputs), and extensive without feed inputs. Boyd et al. (2021a) noted that much of *P. monodon* production in extensive systems does not use feed, but also noted that the data on feed use in Indonesia were particularly scant, such that they did not know how many farms in Indonesia used feed. According to one source, at least some *P. monodon* farms, particularly in the province of Aceh, rely on feed input, (pers comm, Henriksson, 2024), but Boyd et al. (2021a) indicate that this is likely to be low and also only to supplement natural food. Ultimately, the extent of feed use in extensive systems across Indonesia remains uncertain, but as noted, industry experts in Indonesia consulted for this assessment also consider feed inputs to extensive systems to be minimal. Overall, the literature lacks detailed information on the various types of extensive production systems, the number of farms utilizing these techniques in different locations, and the resulting production volumes. Acknowledging some uncertainty, this assessment considers all extensive production collectively, treating it as monoculture systems without feed input.

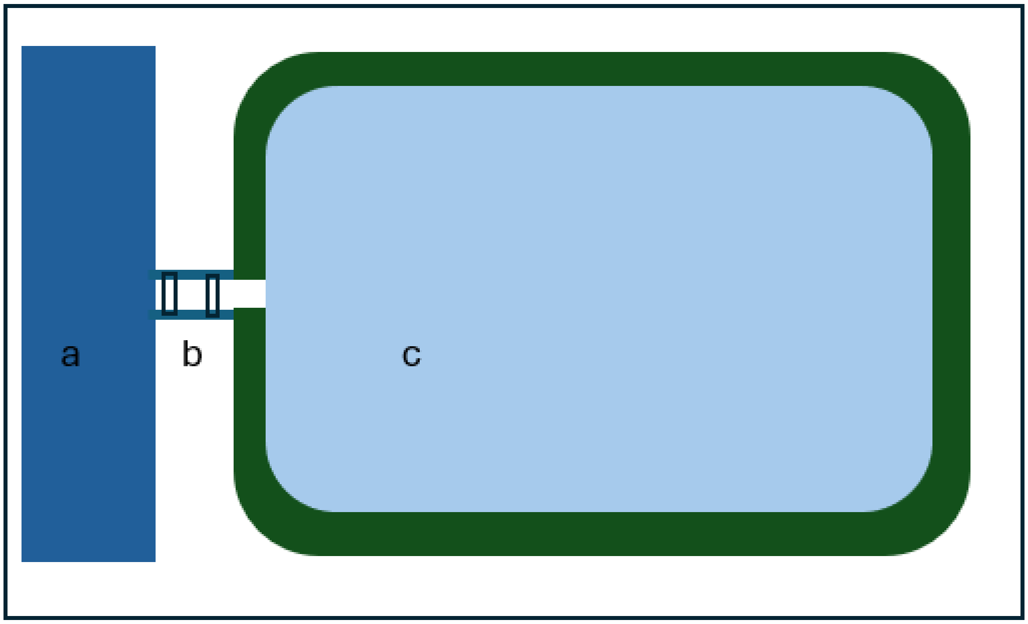

Figure 2: Extensive shrimp pond layout in West Java, Indonesia. Image re-created from Sari, I., 2015 citing Buwono, 1993. Key: a = canal, b = sluice gate, c = pond water.

Semi-Intensive: ≈28% of production/100% L. vannamei

Semi-intensive systems are estimated to account for roughly 28% of shrimp production. For this assessment, only *L. vannamei* is considered to be grown in these systems. Attributes of semi-intensive production systems may include: pond bottoms consisting of either pond liners (HDPE, LDPE), soil, or concrete, with aeration, pumps, application of artificial feed either manually or through automatic feeders, fertilizer application, and some biosecurity measures (SMART-Fish Indonesia, 2023). Ideally, water is pumped from a canal or estuary into a reservoir,[19] then is pumped or flows to a production pond, and finally to a wastewater treatment pond,[20] where, through deposition, particulate organic matter is removed to some degree and water is eventually discharged (SMART-Fish Indonesia, 2023) (MMAF, 2021). Information on the percentage of semi-intensive systems that have incorporated reservoirs is not readily available, but wastewater treatment (i.e., sedimentation ponds) is said to be used on ≈10% of farms (Boyd et al., 2021a). Shrimp post-larvae are sourced from hatcheries and stocked at 20–50 PL/m^2, with a harvest every 4–5 months. Semi-intensive production systems range from 5 to 30 MT/ha/year (Sari, I., 2015, citing Zainun et al. 2007), while more recent estimates are 7 MT/ha/year (pers comm, Budhi Wibowo, 2023, citing Indonesia Shrimp Forum, 2019). Semi-intensive ponds in Indonesia cover ≈0.1–0.5 ha and are about 80 cm deep (SMART-Fish Indonesia, 2023).

Intensive: ≈52% of production/100% L. vannamei

Intensive systems are estimated to account for roughly 52% of shrimp production in Indonesia. For this assessment, only *L. vannamei* is considered to be grown in these systems. Intensive pond systems are,

---

[19] In Indonesia, reservoirs have ≈30% of the capacity by volume of the water as the production ponds.

[20] Wastewater treatment ponds or IPAL use an area of around 10–20% of the grow-out ponds.

on average, smaller in size than semi-intensive ponds, with higher stocking densities and yields, and rely on many inputs such as electricity, feed, fertilizers, aeration, high quality post-larvae, and tighter controls, such as biosecurity and more established infrastructure (MMAF, 2021) (pers comm, Budhi Wibowo 2023, citing Indonesia Shrimp Forum, 2019). Stocking densities are reported to be between 50 and 200 PL/m^2, with harvests ≈30 MT/ha/yr (MMAF, 2021) (pers comm, Budhi Wibowo, 2023, citing Indonesia Shrimp Forum, 2019) (Halim, D. 2016, citing Ministry of Maritime Affairs and Fisheries. Water is pumped from the estuary or sea into a reservoir (typically 30% of the volume of the production ponds); next, into the grow-out ponds; then, flows (or is pumped) to a wastewater treatment pond and eventually discharged (pers comm, Pratiwi, 2021). The frequency of construction and use of reservoirs for incoming water is unclear, while sedimentation ponds are used on ≈10% of *L. vannamei* farms (Boyd et al., 2021a).

Finally, the industry is generally stratified as either a) small independent farms, typically growing *P. monodon* in extensive production systems; or b) small contract farmers, medium or large farms, utilizing semi-intensive or intensive production systems (Yi et al., 2018).

Production System Summary

P. monodon

Black tiger prawn (*P. monodon*) accounts for ≈15% of total shrimp production within the scope of this assessment, of which all are farmed in extensive production systems.

L. vannamei

Whiteleg shrimp (*L. vannamei*) accounts for ≈85% of shrimp production within the scope of this assessment, of which ≈5% are farmed in extensive systems, 28% are farmed in semi-intensive production systems, and ≈52% are farmed in intensive production systems.

Therefore, this Seafood Watch assessment includes four separate ratings and the estimated percentage of production of each rating within the scope of this assessment:

- *P. monodon* in extensive systems | 15% of production
- *L. vannamei* in extensive systems | 5% of production
- *L. vannamei* in semi-intensive systems | 28% of production
- *L. vannamei* in intensive systems | 52% of production

Geographic Spread of Production by Island in Indonesia

Tables 2 and 3 from the Indonesian Government's Statistik-KKP data portal summarize production volume by island and species and production system area by island and type in 2021 and 2022. Table 4 summarizes the estimate of production volume by pond type and island in 2022 following the methodology described in the section, *Estimating volume by production system.* Significant metadata describing the data—such as how the data were gathered, what the definitions are of extensive, semi-intensive, and intensive systems, and how the area of ponds was defined—were not available on the Statistik-KKP website. These insights would be helpful, but the data do help to provide a fairly clear understanding of where production is occurring, and how much. The production volume by system type and island were estimated and are used cautiously (see Table 4). A summary of each table and some key insights follow.

Production volume
According to Indonesia's official statistics,[23] in 2022, Indonesia produced a total of 859,870 MT of *L. vannamei* and *P. monodon* shrimp. *L. vannamei* accounted for the majority of production at 731,252 MT, while *P. monodon* contributed 128,618 MT. Java is the leading shrimp-producing island for both species. Other significant producers include the Lesser Sunda Islands, Sumatra, and Sulawesi. Together, these four islands (Java, the Lesser Sunda Islands, Sumatra, and Sulawesi) account for 93% of Indonesia's total shrimp production.

Compared to 2021, both *P. monodon* and *L. vannamei* production slightly decreased in 2022, by approximately 5,000 MT and 37,500 MT, respectively. The most substantial production declines for *P. monodon* occurred in Sumatra, followed by Sulawesi and Java. For *L. vannamei*, production reductions were most pronounced in Java, Sumatra, and Sulawesi.

Production area by production system type
In 2022, the total land area dedicated to shrimp ponds in Indonesia in 2022 was 822,444 ha, with 747,952 ha for extensive, 48,479 ha for semi-intensive, and 26,013 ha for intensive systems. Sulawesi boasts the largest pond area, followed by Kalimantan, Java, and Sumatra. Nearly all the pond area for Sulawesi (98%) and Kalimantan (99.9%) is for extensive ponds, while pond area is slightly more distributed in Sumatra (57% extensive, 29% semi-intensive, and 56% intensive) and Java (87% extensive, 9% semi-intensive, and 5% intensive).

Kalimantan and Java had relatively stable pond areas for the different pond types in 2021 and 2022. But Sulawesi had a large change in total pond area from 2021 (175,427 ha) to 2022 (330,009 ha), which was primarily driven by an increase in extensive pond area (160,279 ha) and appeared to be an outlier and perhaps an error of data for Sulawesi Utara.[24] Smaller pond area island groupings such as Maluku and the Riau Archipelago also had relatively significant shifts, but the total pond area is quite small compared to the dominant pond area islands of Java, Kalimantan, Sulawesi, and Sumatra.

Estimate of production volume by pond type and island in 2022
The estimated combined total volume of *L. vannamei* and *P. monodon* in 2022 is 866,747 MT, which is a slight overestimation to the actual total of 859,870 MT. The estimated total volume by production system type in 2022 is 519,781 MT from intensive systems, 242,375 MT from semi-intensive, and 104,591 MT from extensive systems.

Estimates by island show a mixture of results. Although Java did produce the most shrimp in 2022, the methods used to estimate production resulted in an underestimation of Java and an overestimation of Sumatra, because of the productivity estimates used favoring the relatively large amount of intensive and semi-intensive pond area of Sumatra. The underestimates of Java, Sulawesi, and Lesser Sunda Islands highlight that the productivity estimates used for semi-intensive and intensive are likely not capturing the complexity and range of actual yields from these systems and locations. Further, the large pond area classification of intensive and semi-intensive in Sumatra are likely not as productive as the productivity estimates used (20 MT/ha/yr and 5 MT/ha/yr, respectively). But when totaled, the under-estimations of semi-intensive and intensive production in Java, Sulawesi, and Lesser Sunda Islands are

---

[23] https://statistik.kkp.go.id/home.php

[24] When comparing island area totals between Clark Labs and Statistik-KKP, they do not agree, with a clear issue with Sulawesi Utara: extensive pond area for Sulawesi Utara from the KKP dataset is 154,445 ha while Clark Labs estimates just 454 ha of ponds in 2022.

somewhat negated with the overestimation in Sumatra. Altogether, in the absence of better data, these results can be cautiously used to help contextualize production by production system type on various islands in Indonesia.

Estimate of total production by volume, species, and production system type

The production volume percentage for each production system type and species stated in the preceding production system section was multiplied by the 2022 reported total production volume to estimate the total production volume by species and production system type (see Table 5).

According to Statistik-KKP, in 2022, the total volume was 128,980 MT for *P. monodon* and 730,890 MT for *L. vannamei*, resulting in a combined total volume of 859,870 MT. The estimated volume from intensive systems is 52% of total production, or 447,132 MT of production in 2022. Semi-intensive volume is 28% of total production or 240,763 MT, and extensive volume is 20% or 171,974 MT, of which 75% is *P. monodon* or 128,980 MT and 25% is *L. vannamei* or 42,993 MT.

Import and Export Sources and Statistics

In 2021, total shrimp exports from Indonesia exceeded 250,000 MT,[25] showing a steady increase from approximately 130,000 MT in 2012 (Data One Portal, 2022). In 2022, Indonesia was the third-largest supplier of shrimp to the United States (NOAA, 2022). According to U.S. National Oceanic Atmospheric Administration (NOAA) seafood database, shrimp exports from Indonesia to the United States in 2022 totaled roughly 166,922 MT, behind Ecuador (199,794 MT) and India (303,583 MT).

By value, shrimp exports were valued at USD1.74 billion in 2018, where the United States is the highest export destination for shrimp by value (66.6%), followed by Japan (19.23%), the European Union (4.54%), Southeast Asian countries (2.17%), and China (1.95%) (Dahuri, R., 2020).

Common and Market Names

Scientific Names	*Litopenaeus vannamei*	*Penaeus monodon*
Common Names	Pacific white shrimp, whiteleg shrimp, western white shrimp, shrimp	Black tiger shrimp, black tiger prawn, Asian tiger shrimp, tiger shrimp, tiger prawn, giant tiger prawn
United States	Whiteleg shrimp	Tiger shrimp
Spanish	Camarón patiblanco	Langostino jumbo
French	Crevette pattes blanches	Crevette géante tigrée

Product Forms

According to NOAA Fisheries import data,[26] the majority of shrimp from Indonesia are in the form of frozen shell-on or peeled, but other listed forms include breaded (frozen) and “other preparations”; a small amount is canned.

---

[25] Data from the Indonesian Department of Marine Affairs: https://statistik.kkp.go.id/home.php

[26] NOAA Fisheries—Foreign Trade: https://www.fisheries.noaa.gov/foss/f?p=215:2:15163475375365::NO:::

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: having robust and up-to-date information on production practices and their impacts available for analysis.

Criterion 1 Summary

	L. vannamei		***P. monodon***
	Semi-intensive & Intensive	**Extensive**	**Extensive**
Data Category	**Score (0–10)**	**Score (0–10)**	**Score (0–10)**
Industry or production statistics	5	5	5
Management	5	5	5
Effluent	5	5	5
Habitat	5	5	5
Chemical use	2.5	2.5	2.5
Feed	5	5	5
Escapes	2.5	2.5	2.5
Disease	2.5	2.5	2.5
Source of stock	10	10	5
Wildlife mortalities	2.5	2.5	2.5
Escape of secondary species	5	5	5
Total	**50**	**50**	**45**
C1 Data Final Score (0–10)	**4.55**	**4.55**	**4.09**

Brief Summary

Given the technical and geographical complexity of the shrimp farming industry, it is perhaps inevitable that data availability and quality in Indonesia is fundamentally challenging. For a globally important shrimp aquaculture industry and an important source of exports to the U.S. seafood market, the readily available information is limited. As a result, describing and assessing the environmental impacts is challenging, and robustly identifying the risk and the burden associated with each species and production system across Indonesia is typically not possible (thus, some or all production systems and species must be grouped together for some criteria because of this inability to decouple impacts).

The most significant and effective information came from an in-country Seafood Watch Fellow, who organized a meeting with key stakeholders in September 2021 to gather information for this assessment. Feedback was recorded in the form of categorized notes and submitted documentation, and was followed up with additional targeted questions on the management, enforcement, practices, and impacts of shrimp farming. These discussions were updated with further stakeholder interviews in October 2023 and resulted in substantial information regarding regulations and management. Information on farm practices, production systems, biosecurity, and ecological impacts was also gathered from primary and grey literature, but significant gaps in knowledge and the robustness of data remain. For this Seafood Watch assessment, the limitations in data availability necessitate a precautionary approach to the scoring in many criteria.

Although there is some variability in data availability between production systems and species, the overall score for Criterion 1—Data is 4.55 out of 10 for extensive, semi-intensive, and intensive *L. vannamei*, and it is based largely on the available academic studies and the regulatory and management data submitted from stakeholders. For extensive *P. monodon*, the uncertainty regarding the sustainability of the *P. monodon* broodstock fishery results in a slightly lower score for Criterion 1—Data of 4.09 out of 10.

Justification of Rating

As follows, publicly available data and information on shrimp farming in Indonesia are somewhat limited, partly due to the complex nature, geographic spread, and scale of the industry. Therefore, Seafood Watch conducted a stakeholder consultation exercise to gather information directly from industry experts. A meeting with key stakeholders was held in September 2021, with feedback documented in the form of categorized notes and submitted documentation. In addition, a survey document was circulated to all willing participants to collect more granular level information about the management, enforcement, farming practices, and impacts of shrimp farming in Indonesia. The results of this process allowed for a substantial amount of information (> 300 documents) to be collected, submitted, and reviewed for this assessment. These discussions were also updated with further interviews in October 2023 and in April of 2025.. The stakeholders and employees from the following organizations were involved (other organizations were also involved but requested to be cited anonymously):

- World Wildlife Foundation (Indonesia)
- Indonesia’s Ministry of Marine Affairs and Fisheries
- Global Quality and Standards Programme (GQSP) United Nations Industrial Development Organization (UNIDO) (referred to in text citations as GQSP)
- Central Proteina Prima (CPP)
- AP5I Indonesian Fishery Producers Processing and Marketing Association
- Shrimp Club Indonesia (SCI)
- Forum Udang Indonesia (FUI)
- JALA Tech
- Delos Aqua

The information gathered from this exercise is referred to throughout this report. All information provided from the surveys is referenced as “pers comm, organization/company or personal last name, year” and other sources and documents provided are cited following APA format. In addition, any remaining data gaps are described in relation to each criterion of this assessment.

Industry or Production Statistics

Data on total production volumes by species and location (to the province level) were available from 2021 to 2022 from the Indonesian government through the Data One Portal.[27] The UN Food and Agriculture Organization (FAO) also provides production volume data by shrimp species over time. Production area by production system type was also available from the Data One Portal or Statistik-KKP[28] and appears to be generally helpful, but there are concerns of its accuracy, considering some of the data outliers (e.g., Sulawesi Utara) and the lack of metadata. To estimate the volume by production system type and location (province/island), estimates of yield or productivity were derived from the literature. The resulting estimate of production volume by production system type and island in 2022 could be used cautiously to help provide a general understanding of the industry. Total volume by production system type and species was also estimated (see the Species Overview), with a moderate level of confidence/quality.

Despite these insights, a major limitation to the assessment is the inability to decouple ecological impacts by species and production systems across the major shrimp farming islands of Indonesia, because of poor spatial understanding of the industry by species and production system type along with the general farm practices of these differing systems. General and nongeospatial-specific insights into production system design were gathered from literature and were generally useful, but a more robust survey/understanding of regional differences of system design and performance is needed. This affects the ability of each criterion to evaluate the ecological impact of the different production systems and species under the scope of this report. As a result, the availability and quality of industry and production data is considered moderate, because there is useful information (e.g., volume by species and island, pond area by production system type and island) that allows for total production system type volume estimates, but more granular data, such as production system volume by region and species, hamper some aspects of this assessment. The Data score is 5 out of 10.

Management and Regulations

The majority of the information gathered during the stakeholder consultation was on laws, regulations, and industry guidelines. This helped to create verified documentation of the current management and regulatory framework in Indonesia, which has rapidly changed since 2020. But Indonesia is a decentralized nation with complex national, provincial, and district level legislation, regulations, and agencies; finding the connectedness between all levels of government was challenging and is not readily available or clear. Given the complicated governing framework, the resulting uncertainty and limitations limit the robustness of the assessment and its findings. Thus, the data provided are considered useful but some uncertainty remains. The Data score is 5 out of 10.

Effluent

There does not appear to be a readily available comprehensive resource of water quality monitoring data of coastal waterbodies. In addition, academic studies on the effluent impacts (or the lack thereof) to public waterways (particularly with sufficiently robust sample sizes and distribution) were not readily available. Thus, the quality of effluent data for this assessment is considered low–moderate because of limitations in evaluating shrimp farming effluent impacts, so the risk-based assessment was completed. A risk-based assessment has two factors: the first estimates the nutrient waste discharged from farms, and the second evaluates the regulatory and enforcement framework and its effectiveness (see the preceding Management and Regulations). Regarding the former, there was a lack of robust protein

---

[27] https://statistik.kkp.go.id/home.php?m=prod_ikan_prov&i=2

[28] https://statistik.kkp.go.id/home.php?m=luaslahan&i=7

content and economic feed conversion (eFCR) values in the literature and a limited understanding of fertilizer application and feeding practices. To estimate effluent nutrient waste discharge, the protein content and eFCR for *L. vannamei* semi-intensive and intensive systems were estimated from academic literature and, when applicable, ASC certification audits. For extensive production of *P. monodon* and *L. vannamei*, peer-reviewed academic information describing or confirming feed use (or the lack thereof) and fertilizer use (i.e., type, ingredients, frequency of application, and/or amount) was quite limited (although this may stem from their limited use in practice). But industry guidance documents and personal communication information were available to help provide some useful information for fertilizer application. The score for Effluent is 5 out of 10.

Habitat

Historical habitat conversions for shrimp farming in Indonesia are documented in academic literature. More recent (since 2000) conversion and development of shrimp farming in Indonesia, its islands, and provinces is less clear. The best available data are from the Clark Labs, which use satellite imagery to document and estimate habitat conversion (land use change) in shrimp farming regions like Indonesia. But the analysis does not distinguish the species produced in ponds within the broad assessment of brackish-water pond aquaculture. This creates some doubt as to how much of the land use change is due to shrimp farming, but recent literature continues to cite shrimp farming as an ongoing conversion driver in highly important coastal habitats such as mangroves. There is also ambiguity about the production systems and species that are farmed in the more recent conversion of coastal habitat. There is a need to evaluate the cumulative impact of the shrimp farming industry, and others, in Indonesia on the coastal ecosystems (i.e., mangroves, coral reefs, seagrass, wetlands), and to identify the health and functionality of these systems. This is a key information gap within the literature that could help to identify the carrying capacities of ecosystems, especially as Indonesia plans for greater production of the aquaculture industry in the near term. Overall, the data are considered moderate, with a score of 5 out of 10.

Chemical Use

There is limited information on chemical use in Indonesian shrimp farming. Insights such as the type, frequency, dose, and potential impact of antimicrobial use on farms are limited, and there are few studies on antimicrobial resistance on shrimp farms in Indonesia. Some insights were provided through personal communications with shrimp farm stakeholders, but the applicability of the responses across the industry, or by species, production system, or region, was unclear. The type and use of other pond chemicals (soil preparation, pesticides, herbicides, etc.) were gathered from stakeholders and the literature. Altogether, data availability for chemical use is considered low–moderate, because there is insufficient information readily available to confidently understand chemical use on farms or any potentially associated ecological impacts. The data score is 2.5 out of 10.

Feed

Data describing feeding practices were limited, especially for extensive production of *P. monodon* and *L. vannamei*. One researcher mentioned that there was significant feed input for *P. monodon* farms, at least in Aceh; however, without further details, it was challenging to extrapolate this observation to all extensive *P. monodon* farms in Indonesia or infer for all extensive systems. Therefore, there is uncertainty in the assumption that there is no feed used for *P. monodon* and *L. vannamei* extensive production, and the data score for Feed is 5 out of 10.

Some limited information on feed ingredients and inclusion levels for shrimp feed was provided by shrimp feed manufacturers for this assessment. To develop a representative feed ingredient list and inclusion levels for this assessment, data were pulled from academic literature, personal communications with feed manufacturers, and audits of certified Aquaculture Stewardship Council (ASC) companies. Similarly, data points for protein content and eFCR were also estimated from literature sources. Some information was provided to help define the marine ingredient sources (e.g., species, fishery, inclusion levels), but there were some key missing data (e.g., fishing method, location of fishing, and supporting certification documentation). These data were provided by two feed manufacturers, whose combined market share represents approximately 30% of Indonesian shrimp feeds. Overall, the data score is considered moderate for fed species. The Feed criterion data score is 5 out of 10.

Escapes

Data describing escapes at the farm level or industry level were not readily available. Approximations of escape risk are derived from data that describe the climate (i.e., rainfall flooding events), farm practices, the measure of the openness of the production system, the locations of farms compared to flood zones, and biosecurity, though there were limitations in data richness across production systems and provinces. Documentation of escaped shrimp in the wild was not readily available, while the genetic introgression and/or competitive interactions of either native *P. monodon* or nonnative *L. vannamei* are not well understood in the wild. As a result, data quality for Escapes is considered low–moderate and scores 2.5 out of 10.

Disease

At the global level, there is a large body of literature on shrimp diseases, but spatial and temporal information by species or production system regarding disease outbreaks, type, mortalities, and treatments specifically in Indonesia[29] were not readily available. Some data were available describing disease prevalence over time, but further insights such as sampling methodology and representativeness of the data were not available. Governance describing biosecurity strategies to mitigate disease outbreaks and spread was available from literature and stakeholders. Evidence of disease transmission from farms to wild species is limited, and further research is needed because the risk of impacts to wild populations (compared to those in farms) from pathogens commonly found in shrimp farms continues to be uncertain. Altogether, data describing disease is low–moderate and scores 2.5 out of 10.

Source of Stock

The quality of data describing broodstock and hatchery-produced post-larvae is high for *L. vannamei* and moderate for *P. monodon*. The source of broodstock for *P. monodon* is wild fisheries, but there is limited information about these specific fisheries, such as comprehensive stock assessments, so the health of the fishery is not well defined. It is well established that *L. vannamei* broodstock and post-larvae are sourced from domesticated breeding centers and hatcheries. Therefore, the data quality is considered moderate and scores 5 out of 10 for *P. monodon,* while the data quality is considered high and scores 10 out of 10 for *L. vannamei*.

Wildlife Mortalities

Literature describing farm biosecurity measures regarding wildlife was available. The farm siting process and the ecological considerations were also well described. But insights into species-level protections, farm practices, or interactions with wild species were not well understood or readily available. The

---

[29] Indonesia does not appear to report quarterly disease to the Network of Aquaculture Centres in Asia-Pacific (NACA) https://enaca.org/?id=8 and data from the World Organization for Animal Health and quantitative data dashboard only contains limited data from 2016 to 2019 for Indonesia.

International Union for the Conservation of Nature (IUCN) Red List details the significant indirect impact that Indonesian shrimp farming has on species through habitat degradation, although there was no direct evidence of lethal control to the IUCN listed species. There is reporting of piscicide use, but what species are affected and how widely piscicides are utilized is not well known. As a result, data quality is considered low–moderate and scores 2.5 out of 10.

Introduction of Secondary Species

Information describing the percentage of production reliant on trans-waterbody movement and the biosecurity measures at the source and destination of such movements is moderate. Data estimating the percentage of broodstock imported into Indonesia and the country of origin were available from academic literature and personal communications with Indonesian shrimp farming stakeholders; however, the robustness is uncertain. The movement of wild caught broodstock is also not well understood. For example, the location of major *P. monodon* ports, the quarantine requirements and process, and the control of movement are not well detailed, but some useful information is available and personal communications helped to provide a general narrative. The biosecurity of sources (e.g., international facilities supplying broodstock) are well understood, but academic studies or industry briefs describing the biosecurity of shrimp hatcheries in Indonesia were not readily available. The IndoGAP standard for shrimp hatcheries was available and helped to describe the biosecurity principles for certified hatcheries, but how representative IndoGAP-certified hatcheries are of the industry is uncertain. Information describing the biosecurity of typical farms (the destination) across production system types was not readily available. Therefore, the data quality is considered moderate and scores 5 out of 10.

Conclusions and Final Score

Given the technical and geographical complexity of the shrimp farming industry, it is perhaps inevitable that data availability and quality in Indonesia is fundamentally challenging. For a globally important shrimp aquaculture industry and an important source of exports to the U.S. seafood market, the readily available information is limited. As a result, describing and assessing the environmental impacts is challenging, and robustly identifying the risk and the burden associated with each species and production system across Indonesia is typically not possible (thus, some or all production systems and species must be grouped together for some criteria because of this inability to decouple impacts).

The most significant and effective information came from an in-country Seafood Watch Fellow, who organized a meeting with key stakeholders in September 2021 to gather information for this assessment. Feedback was recorded in the form of categorized notes and submitted documentation, and was followed up with additional targeted questions on the management, enforcement, practices, and impacts of shrimp farming. These discussions were updated with further stakeholder interviews in October 2023, and resulted in substantial information regarding regulations and management. Information on farm practices, production systems, biosecurity, and ecological impacts was also gathered from primary and grey literature, but significant gaps in knowledge and the robustness of data remain. For this Seafood Watch assessment, the limitations in data availability necessitate a precautionary approach to the scoring in many criteria.

Although there is some variability in data availability between production systems and species, the overall score for Criterion 1—Data is 4.55 out of 10 for extensive, semi-intensive, and intensive *L. vannamei*, and is based largely on the available academic studies and regulatory and management data submitted from stakeholders. For extensive *P. monodon*, the uncertainty regarding the sustainability of the *P. monodon* broodstock fishery results in a slightly lower score for Criterion 1—Data of 4.09 out of 10.

Criterion 2: Effluent

Impact, unit of sustainability and principle

- Impact: Aquaculture species, production systems and management methods vary in the amount of waste produced per unit of production. The combined discharge of farms, groups of farms or industries contribute to local and regional nutrient loads.
- Sustainability unit: The carrying or assimilative capacity of the local and regional receiving waters.
- Principle: not allowing effluent discharges to exceed, or contribute to exceeding, the carrying capacity of receiving waters at the local or regional level.

Criterion 2 Summary

Effluent Risk-Based Assessment	*L. vannamei*		*P. monodon*	
Effluent parameters	**Value**	**Score**	**Value**	**Score**
Intensive Production Systems				
F2.1a Waste (nitrogen) production per ton of fish (kg N MT^{-1})	47.38			
F2.1b Waste discharged from farm (%)	27.00			
F2.1 Waste discharge score (0–10)		8		
Semi-Intensive Production Systems				
F2.1a Waste (nitrogen) production per ton of fish (kg N MT^{-1})	49.36			
F2.1b Waste discharged from farm (%)	27.00			
F2.1 Waste discharge score (0–10)		8		
Extensive Production Systems				
F2.1a Waste (nitrogen) production per ton of fish (kg N MT^{-1})	41.71		39.95	
F2.1b Waste discharged from farm (%)	18.00		18.00	
F2.1 Waste discharge score (0–10)		9		9
All Production Systems				
F2.2a Content of regulations (0–5)		3		3
F2.2b Enforcement of regulations (0–5)		2		2
F2.2 Regulatory or management effectiveness score (0–10)		2.4		2.4
Intensive C2 Effluent Final Score (0–10)	**6.00**			
Semi-Intensive C2 Effluent Final Score (0–10)	**6.00**			
Extensive C2 Effluent Final Score (0–10)	**7.00**		**7.00**	

Brief Summary

In unfed extensive *P. monodon* and *L. vannamei* shrimp farms, fertilizer application is the primary nutrient input that may pollute surrounding waterbodies if discharged in effluent. Although data are limited, it was estimated that 80 kg/ha of inorganic fertilizer (urea) are used, and with low shrimp yields per hectare (i.e., low nutrient outputs in harvested shrimp), the estimated net nitrogen in soluble and particulate waste is 39.95 kg N per MT of *P. monodon* and 41.71 kg N per MT of *L. vannamei* production in extensive systems. In fed *L. vannamei* semi-intensive and intensive systems, feed and fertilizer represent the primary nutrient inputs. For *L. vannamei* grown in intensive ponds (with an estimated feed protein content of 33.6%, an eFCR of 1.4, and urea fertilizer use of 0.6 kg N per MT of shrimp production), the resulting waste production is 47.38 kg N per ton of *L. vannamei.* In semi-intensive systems (with an estimated feed protein content of 33.6%, an eFCR of 1.4, and fertilizer use of 2.58 kg N per MT of shrimp production), the resulting waste production is 49.36 kg N per ton of *L. vannamei.* Considering the nutrient dynamics in ponds as well as the typical water exchange rates, water treatment, and the collection and appropriate disposal of sludge (although varying between production systems), 18% of the waste N produced is considered to be discharged from extensive systems, resulting in a score for Factor 2.1—waste discharge of 9 out of 10 for *L. vannamei* and *P. monodon.* For semi-intensive and intensive systems growing *L. vannamei,* 27% of the waste N produced is considered to be discharged, resulting in a score of 8 out of 10.

Indonesia has a new legislative framework for natural resource management, which covers shrimp farming, and itis intended to be an area-based, cumulative management system. There are also provincial/subnational spatial management plans, which set a goal of an area-based, cumulative management framework. But the necessary integration of aquaculture with other socioeconomic industries appears to be lacking. Wastewater treatment and water quality standards are additional core ecological principles to regulate and limit effluent pollution within the carrying capacity of receiving waters; however, despite updated water quality discharge limits for shrimp farms, there is no readily available evidence to suggest that these limits are prescriptive to the various waterways, locations, and ecosystems into which shrimp farms discharge effluent in Indonesia. There are new requirements for sedimentation ponds that may help to reduce the evidence of coastal degradation (for which shrimp aquaculture wastewater is a significant source,) but their implementation appears lacking. Overall, the management system does appear to set effluent discharge limits, but there is no evidence to suggest that they are set to minimize area-based or cumulative-level impacts. The score for Factor 2.2a—content of regulations is a moderate 3 out of 5.

Enforcement of effluent management measures appears to be limited. The agencies enforcing effluent limits are active, but they may have limitations in resources. The intended frequency of farm visits depends on the size of the farm and the compliance history. Data demonstrating enforcement of these inspections are lacking, and the inconsistency of inspections and the lack of anidentifiable strategy limit the potential enforcement effectiveness. There is considered to be area-level monitoring of waterbodies, but the adaptive management and enforcement principles—such as feedback loops between monitoring noncompliance at the area level and enforcement 'upstream'“” to point or nonpoint sources of shrimp farms appears— to be missing. Importantly, public evidence of compliance and monitoring data is not mandatory, is published inconsistently, and is apparently not readily available. As a result, enforcement measures and monitoring and compliance data are considered limited. The score for Factor 2.2b—enforcement of regulations is 2 out of 5 and is applied to all species and systems.

Combining all factors results in the following Criterion 2—Effluent scores:

- *L. vannamei* intensive, 6 out of 10
- *L. vannamei* semi-intensive, 6 out of 10
- *P. monodon* extensive, 7 out of 10
- *L. vannamei* extensive, 7 out of 10.

Justification of Rating
There was no readily available, comprehensive resource of water quality monitoring data of waterbodies or for farms at scale. In addition, academic studies on effluent impacts with robust sample sizes and distribution to provide high confidence and insight of shrimp aquaculture farming's impact (or lack thereof) to public waterways were not readily available. As a result, the data quality and availability for effluent impacts is considered low–moderate (i.e., a Criterion 1 score of 2.5 out of 10 for the effluent category), so the risk-based assessment methodology was utilized.

The risk-based assessment is based on the amount of waste discharged per ton of production (Factor 2.1), combined with the effectiveness of the management or regulatory structure to control the total farm discharge and the cumulative impact of multiple farms affecting the same receiving waterbody (Factor 2.2).

Factor 2.1—Waste discharged per ton of shrimp production
This factor calculates the amount of waste nitrogen produced by the shrimp (Factor 2.1a), then the percentage of that waste that is discharged from the farm site (Factor 2.1b). Nitrogen is used as a proxy indicator of waste due to the ease of calculation, based on the greater availability of data for the nitrogen in the protein component of feed or as fertilizer.

Factor 2.1a—Biological waste production per ton of shrimp
To estimate the nitrogenous waste produced by shrimp, nitrogenous inputs and outputs are calculated. The nitrogen input calculation adds the nitrogen in feed (if used) to the nitrogen in fertilizer (if used) in the production of 1 MT of shrimp. The nitrogen output is determined by the nitrogen available (as protein) in harvested farmed shrimp. The nitrogen output is then subtracted from the nitrogen input to determine the amount of waste nitrogen produced per ton of farmed shrimp. Note that the eFCR and protein content values for *L. vannamei* grown in intensive and semi-intensive ponds are considered here to be the same, because information differentiating them was not robustly available (see Criterion 5—Feed for more detail). Therefore, they are presented in Factor 2.1a together.

L. vannamei, Intensive and Semi-Intensive Ponds
The primary sources of nitrogen input for intensive and semi-intensive pond production systems growing *L. vannamei* are feed and fertilizers. For shrimp feed, the data for protein content and eFCR were gathered from the literature, feed manufacturers, feed mill association, ASC certification audits, and surveys, and the average is calculated and shown here along with the range of values (see Criterion 5—Feed for more detail). Information characterizing fertilizer use, type, and amount applied by species and/or production system was variable in quality. For example, stakeholder surveys for this assessment indicated that fertilizer is generally used for semi-intensive and intensive systems—inorganic and organic—though not always clearly differentiated by production system, nor was the amount applied provided. Academic literature describing fertilizer usage in these systems was also limited; one paper, Rakhfid et al. (2017), cited two previous papers that state that shrimp farms commonly apply 150–200 kg of urea and 75–100 kg of triple superphosphate (TSP) per hectare (Andarias, 1991) or, more recently, 150 kg of urea and 75 kg of TSP per hectare (Gunarto, 2008). This is also consistent with insight describing extensive and extensive plus production systems (see the following extensive section).

Further communication with stakeholders indicated that little quantities of nitrogen-based fertilizers (16 kg/ha/crop) are currently applied to intensive and semi-intensive systems, because both rely on feed for shrimp growth (pers comm, Widigdo and Kokarkin, 2024, citing pers comm, CPP, 2024), and the initial nitrogen-based fertilization to promote primary productivity is likely done to help with a feed source in the initial post-larval stocking phase. The primary source of fertilizer is from a fermentation of rice bran, molasses, and yeast to help promote beneficial bacteria such as *Bacillus* and *Nitrobacter* (pers comm, Widigdo and Kokarkin, 2024). Because this analysis focuses on nitrogen-based discharge, the fermentation mixture is not considered for this calculation, and it is assumed that 16 kg of urea are applied per hectare per production cycle (based on the most recent expert opinion). This results in two separate calculated fertilizer application rates (kg N MT^{-1}) due to the differing productivity (i.e., harvest yields per hectare) of the two production systems.[30]

Feed Data:
a) Average protein content of feed: 33.6% | Range: 20.5%–40.2%
b) Average Economic Feed Conversion Ratio (eFCR): 1.4 | Range: 1.1–1.7
c) Fertilizer application:[31] 0.60 kg N MT^{-1} intensive | 2.58 kg N MT^{-1} semi-intensive
d) Protein content of harvested whole *L. vannamei* shrimp: 17.8% (Boyd et al., 2007)

For the purposes of this assessment, a protein content of 33.6% and an eFCR value of 1.4 are considered representative (see Criterion 5—Feed for further details regarding these figures). The calculations that were carried out using these figures are:

Intensive

N input per ton of shrimp produced = [a × N content factor (0.16) × b × 10] + c = 75.29 kg N MT^{-1}
N content of harvested shrimp = d × N content factor (0.16) × 10 = 28.48 kg N MT^{-1}
Waste N produced per MT shrimp produced (2.1a) = N input – harvested N = 47.38 kg N MT^{-1}

Semi-Intensive

N input per ton of shrimp produced = [a × N content factor (0.16) × b × 10] + c = 77.84 kg N MT^{-1}
N content of harvested shrimp = d × N content factor (0.16) × 10 = 28.48 kg N MT^{-1}
Waste N produced per MT shrimp produced (2.1a) = N input – harvested N = 49.36 kg N MT^{-1}

<u>*P. monodon* and *L. vannamei,* Extensive, Ponds</u>
With minimal or zero feed used in extensive production (see the production system description in the Introduction), the primary potential source of nitrogen input is fertilizer. Unfortunately, information describing fertilizer application (e.g., use, amount, type, and frequency) for extensive systems in Indonesia is limited, with minimal insight gleaned from the published literature. Some studies and personal insight indicate that the types of fertilizer most commonly applied are inorganic urea and phosphate (i.e., TSP), which are used to stimulate phytoplankton growth (Supriyadi and Rukyani 2000) (Nur 2007) (Florina and Sukardi 2012) (Bunting et al. 2013) (Anonymous 2013a). Recent experimental studies used the same combination of urea and TSP (Pantjara and Kristanto, 2020) (Pantjara et al. 2020).

---

[30] Semi-intensive production systems range from 5 to 30 MT/ha/year (Sari, I., 2015, citing Zainun et al. 2007), while most recent estimates are 7 MT/ha/year (pers comm, Budhi Wibowo, citing Indonesia Shrimp Forum, 2019), so 7 MT/ha/yr is used. Intensive production systems are > 30 MT/ha/year (Halim, D. 2016, citing Ministry of Maritime Affairs and Fisheries), so the lower end of the range, 30 MT/ha/year, is used. Boyd et al. (2021a) estimate that Indonesia *L. vannamei* farms have 2.45 crop cycles per year. The following calculation (semi-intensive as an example) is then used to determine farm production (MT/ha/cycle):

(7 MT/ha/year)/(2.45 crop cycles/year) = 2.86 MT/ha/cycle for semi-intensive production.

[31] To calculate fertilizer application, the following equation is used (semi-intensive is the example):

(1/2.86 MT/ha/cycle) × (16 kg/ha/cycle × 46% N) = 2.58 kg N per MT of *L. vannamei.*

An evaluation of brackish-water aquaculture pond bottom soil in South Sulawesi by Mustafa et al. (2020) found that, on average, fertilizer application of urea was 250 kg/ha per season, but represented potentially a large diversity of culture organisms, including black tiger prawn.[32] Other studies applied urea and TSP fertilizer at about 100 kg/ha at the beginning of each production cycle in extensive *P. monodon* experimental studies (Pantjara and Kristanto, 2020) (Pantjara et al. 2020).

Overall, these studies align with a stakeholder interview that suggested that 150 kg of inorganic and 50 kg of TSP fertilizers are typically applied per hectare, along with fermented fertilizers that are carbon-based (rice brand, molasses, and EM4 probiotic) (pers comm, Anonymous, 2023). This appears to be consistent with industry guidance, where 60–100 kg per ha[33] are recommended to be applied over 10 days for traditional plus systems (SMART-Fish Indonesia, 2023). It has also been reported that as little as 10 kg of urea and 10 kg of TSP are applied per hectare per cycle (pers comm, Widigdo and Kokarkin, citing pers comm, Saenong, 2021).

Therefore, given the range of values provided (10–150 kg), the mean is selected: 80 kg of inorganic fertilizers (urea, 46% N) are applied per hectare for each pond cycle. Calculations for the nitrogen component of total fertilizer inputs are based on the FAO specifications for inorganic urea (46% N) (FAO, 2015c).

To determine a fertilizer application of kg N MT^{-1} of shrimp production, it is necessary to estimate the average production of extensive ponds per hectare. The following observations are then applied. It is estimated that the average yield for extensive farms is < 5 MT per hectare per year (Anonymous, 2021), while Boyd et al. (2021a) estimated pond yields of 1.51 MT/ha/year with a crop frequency (no./year) of 2.88. Using these values, it is estimated that production per harvest is 524.3 kg/ha.[34]

Because there are two different species, *L. vannamei* and *P. monodon*, which have differing protein contents, there are two separate calculations (one for each species), to determine the estimated waste nitrogen per ton of shrimp.

Extensive, *P. monodon*

With no feed use (just fertilizer), the data points used are:

a) Protein content of feed: none
b) Economic Feed Conversion Ratio (eFCR): none
c) Fertilizer application: 70.19 kg N MT^{-1} [35]
d) Protein content of harvested whole *P. monodon* shrimp: 18.9% (Boyd et al., 2007)

---

[32] A variety of crustaceans, tilapia, carp, and seaweed species are listed by Mustafa et al. (2020) as brackish-water culture species in South Sulawesi.

[33] Reported as 300 to 500 kg per pond, and assuming an average extensive pond farm size of 5 ha, because it is reported that extensive ponds size range from 1 to 10 ha (pers comm Pratiwi, 2021).

[34] Calculation for estimated production per harvest is: (1.51 MT/ha/year × 1000 kg/1 MT)/2.88 crops/year = 524.3 kg/ha.

[35] 1/(524.3 kg/ha × 1 MT/1000 kg)) × (46%N × 80 kg/ha/cycle) = 70.19 kg N/MT.

The calculations that were carried out using these figures and used in assessing the production and effects of effluents are:

N input per ton of shrimp produced = [a × N content factor (0.16) × b × 10] + c = 70.19 kg N MT^{-1}
N content of harvested shrimp = d × N content factor (0.16) × 10 = 30.24 kg N MT^{-1}
Waste N produced per ton shrimp produced (2.1a) = N input – harvested N = 39.95 kg N MT^{-1}

Extensive, *L. vannamei*
With no feed use (just fertilizer), the data points used are:
a) Protein content of feed: none
b) Economic Feed Conversion Ratio (eFCR): none
c) Fertilizer application: 70.19 kg N MT^{-1} [36]
d) Protein content of harvested whole *L. vannamei* shrimp: 17.8% (Boyd et al., 2007)

The calculations that were carried out using these figures and used in assessing the production and effects of effluents are:

N input per ton of shrimp produced = [a × N content factor (0.16) × b × 10] + c = 70.19 kg N MT^{-1}
N content of harvested shrimp = d × N content factor (0.16) × 10 = 28.48 kg N MT^{-1}
Waste N produced per ton shrimp produced (2.1a) = N input – harvested N = 41.71 kg N MT^{-1}

Factor 2.1a Summary
Using the limited data available, the net excess nitrogen in soluble and particulate waste across the four species/system combinations is calculated to be:

- 47.38 kg N per ton of *L. vannamei* production in intensive systems
- 49.36 kg N per ton of *L. vannamei* production in semi-intensive systems
- 39.35 kg N per ton of *P. monodon* production in extensive systems
- 41.71 kg N per ton of *L. vannamei* production in extensive systems

Factor 2.1b—Production system discharge
This factor estimates the percentage of the waste produced by shrimp that leaves the farm in effluent. Attributes of farm practices and pond design that determine the score of this factor are water exchange rates, wastewater treatment design and retention time, the appropriate disposal of sludge, and any other applicable practices that may limit waste discharge into the environment. Unfortunately, because of the common use of unclear terminology, determining water discharge characteristics is challenging; for example, "water exchange" may refer to exchanges between the production ponds and the external environment, or to exchanges between production ponds and reservoirs or other treatment ponds within the farm boundary. Similarly, reservoirs or settling ponds may be used with influent water before use in production ponds, or used with effluent water before discharge from the farm (or both). The term "clarifying pond" used by Tu et al. (2021) could refer to either a reservoir for influent or a settling pond for effluent. Boyd et al. (2021a, 2021b, 2017) are specific regarding the use of reservoir/settling ponds and are a useful resource.

In general, there is likely to be a large range of water management and discharge characteristics across (and within) different production systems and even within the production systems described here. The

---

[36] 1/(524.3 kg/ha × 1 MT/1000 kg) × (46% N × 80 kg/ha/cycle) = 70.19 kg N/MT.

following attempts to summarize the available information and to draw simple conclusions for each production system assessed from a typical farm.

L. vannamei, Intensive, Ponds

Although the design and engineering of intensive ponds can vary, intensive systems have been described and/or recommended to have the following water flow path: water is commonly pumped into a reservoir from the sea or estuary; next, eventually flows into the production ponds; then, into a wastewater treatment pond (i.e., sedimentation pond) and discharged (Taw, N., 2017) (pers comm, Pratiwi, 2021) (GQSP, 2021). But based on the numerous stakeholders contacted for this report, it is unclear how many intensive shrimp farms have adopted reservoir and/or treatment/sedimentation ponds.

Stakeholder interviews indicate that there are farms (semi-intensive and intensive) with sedimentation ponds (Taw, N., 2017) (pers comm, Pratiwi, 2021) (pers comm, Sullivan, 2023) (pers comm, MMAF, CPP, GQSP UNIDO, FUI, 2021), and it does appear that regulations now require sedimentation ponds sized to 30% of the grow-out pond area (see Factor 2.2) (Regulation Of The Minister Of Marine And Fisheries Concerning Standards Of Business Activities And Products On The Implementation Of Risk-Based Business Licenses In The Marine And Fishery Sector. No. 10, 2021). But data supporting the widespread usage of sedimentation ponds are limited.

A survey conducted by Boyd et al. (2021a) reported that about 10% of *L. vannamei* farms had sedimentation ponds. Further details into the sample location for the Boyd et al. (2021a) report or the types of production systems described were not available in the publication [which cites a survey sample approach and data from Juarez (2021), but the text, *The Shrimp Book 2*, was not readily available]. Regionally, it is common for more intensive farms in Banyuwangi to have sedimentation ponds, and second-generation farmers are building wastewater treatment (i.e., sedimentation ponds) and reservoirs (pers comm, Faturakhmat, 2023). But across the country, it does appear that the implementation of sedimentation ponds needs to improve across the industry (pers comm, Faturakhmat, 2023), with one source speaking on anonymity stating that the adoption rate is quite low, with low enforcement (pers comm, Anonymous, 2023). One of the main barriers to implementation in general is cost; i.e., the cost of construction and the opportunity cost of removing grow-out pond area for sedimentation ponds because space is limited (pers comm, Faturakhmat, Farthing, Desyana, 2023). In 2024, the IndoGAP standard will become mandatory, and farms must provide proof of sedimentation or filtration of effluent (see Factor 2.2), but until this is shown to be effectively enforced (and the widespread use of wastewater treatment systems is demonstrated), it is assumed that the majority of intensive farms in Indonesia do not have sedimentation ponds.

Information describing water exchange rates for a typical intensive farm is limited, but the Indonesian National Standard for intensive *L. vannamei* production describes on average water exchange exceeding > 3% daily (pers comm, MMAF, 2021, citing SNI for intensive *vannamei*). This is further supported by personal communication with industry stakeholders, who indicated an exchange rate of > 3% but with a range of values with unclear applicability to semi-intensive systems, intensive systems, or both.[38] A survey of 133 *L. vannamei* farms in Indonesia (production system type was undefined) broadly concurred, finding that water exchange rates were an average of 12% per day (Boyd et al., 2021a). As noted, it is not clear if these exchanges are within the farm (e.g., through sedimentation ponds) or involve discharges into natural waterbodies.

After harvest, 97% of intensive pond farmers dried ponds before starting a new crop cycle, and 99% used either chemical or nonchemical methods for pond preparation (Delphino, M. et al., 2022), which is confirmed through stakeholder interviews (pers comm, Faturakhmat, 2023). According to the stakeholder meetings and interviews, the pond soil bottom "sludge" is repurposed (e.g., fertilizer for agriculture or canal plant biofilters; reinforcement of pond dikes and embankments) (pers comm, Pratiwi, and Anonymous, 2021) (pers comm, Widigdo and Kokarkin, 2024). According to Merican (2015), almost 90% of farms in Indonesia have installed some type of equipment or system to remove pond sludge or accumulated organic materials.

In summary, the average daily water exchange rate of intensive ponds is considered to be > 3%. Greater clarity is needed of the data describing effluent filtration by production system type and of how commonly these techniques (e.g., sedimentation ponds, residence time) are adopted across the industry. Given the limited information available, it cannot be assumed that all intensive production systems do have sedimentation ponds, but there is an adjustment for proper disposal of sludge (from grow-out ponds). This results in an estimated production system discharge of 27%;[39] that is, 27% of the waste produced by the shrimp is considered to be discharged from the farm as effluent.

L. vannamei, Semi-Intensive, Ponds

From the limited information available, it appears that, after use, pond water either a) flows to a wastewater treatment pond (i.e., settling pond) and is eventually discharged, or b) is discharged directly to external waterways (Taw, N., 2017) (pers comm, CPP, Faturakhmat, MMAF, GQSP UNIDO, 2021). The surveys by Boyd et al. (2021a) did not distinguish between production system type (intensive and semi-intensive) for *L. vannamei* farms, but they estimated that only 10% of farms have settling basins. Because of limited data availability, this is used as justification to assume that a minority of semi-intensive farms implement wastewater treatment; thus, the typical semi-intensive *L. vannamei* farm does not have wastewater treatment. Information describing water exchange rates specifically for semi-intensive production systems is limited, and the data described here primarily rely on survey responses from stakeholders for this assessment (as for intensive systems). This suggests that daily exchange rates are > 3%, which is also supported by the Boyd et al. (2021a) surveys, with an average exchange rate of 12% per day. With little use of sedimentation ponds, these water exchanges are considered to involve discharges to natural waterbodies.

---

[38] Daily pond exchange rates differ across the survey respondents for this assessment. An anonymous contact states a 400% exchange rate over the production cycle (≈3.3% per day), which is likely intensive production. AP5I provided a range of exchange rates during the production cycle, stating no exchange for the first month, then progressively higher exchanges from the second to fourth months, starting at 7.5% to 10% then increasing to 10–15% every 2 to 3 days, which roughly averages from 2.6% to 10% per day over the cycle. An anonymous source estimates ≈10% water exchange for farms in Banyuwangi, representing intensive to extensive systems. GQSP UNIDO and MAFF estimate daily water exchanges of > 5%, with increasing exchanges toward the end of the production cycle (up to 20%). JALA Tech estimates 5–10% on average.

[39] According to the SFW Aquaculture Standard, it is estimated that 51% of pond effluent is discharged with an average annual daily exchange of > 3%, but because pond sludge is disposed of properly, the discharge score is modified to 27% (51% – 24%).

Ponds are typically drained at harvest (though with limited fallowing time), and 90% of farms remove and manage sludge in some way (e.g., fertilizer for agriculture or canal plant biofilters; reinforcement of pond dikes and embankments) (pers comm Pratiwi, and Anonymous, 2021) (Merican, 2015) (Delphino, M. et al., 2022) (pers comm, Faturakhmat, 2023).

Overall, robust data are limited and figures vary, but it is assumed that the average daily water exchanges over a typical production cycle are > 3% per day for semi-intensive production systems. There is an adjustment for proper disposal of pond sludge. Because there is no use of a sedimentation pond, the estimated production system discharge is 27%[40]; that is, 27% of the waste produced by the shrimp is considered to be discharged from the farm as effluent.

P. monodon and *L. vannamei*, Extensive, Ponds

P. monodon and *L. vannamei* extensive pond culture in Indonesia rely upon the incoming tide to exchange water within the pond, while water is discharged at low tide to a depth determined by the sluice gate height (pers comm, Pratiwi, 2021) (Sari, I., 2015). Although the exact water exchange practices are challenging to define, extensive pond systems are by definition dependent on tidal exchange, with limited use of mechanical pumping (Bunting et al., 2013). The average water exchange rate is typically < 3% per day (pers comms Saenong, 2025). It is doubtful that extensive systems have constructed sedimentation ponds, considering the use of tides for water exchange; and, given that these are low-input systems, the production ponds themselves are likely to create hydrological characteristics similar to those of sedimentation ponds.

Without the use of feed (or only minimal amounts), the buildup of particulate wastes in extensive ponds is slower than in intensive ponds, and the removal of sludge is likely intermittent. According to Merican (2015), almost 90% of farms in Indonesia have installed some type of equipment or system to remove pond sludge or accumulated organic materials. 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) (Tarunamulia et al., 2019) (pers comm, Susanto, 2023). The frequency of sludge removal is at least once every 2 years (pers comm, Desyana, 2023).

Therefore, without more clear data describing the typical extensive pond wastewater treatment, it is assumed, through a precautionary perspective, that no wastewater treatment is implemented. With an exchange rate < 3%, and an adjustment for the proper disposal of pond sludge to reinforce pond walls, the estimated production system discharge is 18%.[41]

Conclusion—Factor 2.1

The estimated waste nitrogen calculated in Factor 2.1a is combined with the production system discharge adjustments in Factor 2.1b for an estimated total waste discharge per species and production system. The resulting estimated waste values and resulting scores are summarized:

---

[40] According to the SFW Aquaculture Standard, it is estimated that 51% of pond effluent is discharged with an average annual daily exchange of > 3%, but because pond sludge is disposed of properly, the discharge score is modified to 27% (51% – 24%).

[41] According to the SFW Aquaculture Standard, it is estimated that 42% of pond effluent is discharged with an average annual daily exchange of < 3%, but because pond sludge is disposed of properly, the discharge score is modified to 27% (42% – 24%).

L. vannamei, Intensive, Ponds

L. vannamei grown in intensive ponds has an estimated waste production of 47.38 kg N per ton of *L. vannamei* production, of which an estimated 27% is discharged from the pond (i.e., 12.79 kg N MT^{-1}). This results in a final score for Factor 2.1—waste discharged per ton of shrimp of 8 out of 10.

L. vannamei, Semi-Intensive, Ponds

L. vannamei grown in semi-intensive ponds has an estimated waste discharge of 49.36 kg N per ton of *L. vannamei* production, of which an estimated 27% is discharged from the pond (i.e., 13.33 kg N MT^{-1}). This results in a final score for Factor 2.1—waste discharged per ton of shrimp of 8 out of 10.

P. monodon, Extensive, Ponds

P. monodon grown in extensive ponds has an estimated waste discharge of 39.95 kg N per ton of *P. monodon* production, of which an estimated 18% is discharged from the pond (i.e., 7.50 kg N MT^{-1}). This results in a final score for Factor 2.1—waste discharged per ton of shrimp of 9 out of 10.

L. vannamei, Extensive, Ponds

L. vannamei grown in extensive ponds has an estimated waste discharge of 41.71 kg N per ton of *L. vannamei* production, of which an estimated 18% is discharged from the pond (i.e., 7.19 kg N MT^{-1}). This results in a final score for Factor 2.1—waste discharged per ton of shrimp of 9 out of 10.

Factor 2.2—Management of farm-level and cumulative impacts

Factor 2.2a—Content of effluent management measures

In this factor, effluent regulations or other management measures are considered, to assess how discharged wastes from shrimp farms are being managed at the farm and industry level.

Agencies

Broadly, the Ministry of Environment and Forestry (MoEF) is responsible for key environmental regulatory matters at a national level, while the Ministry of Marine Affairs and Fisheries (MMAF) and the Directorate General of Aquaculture are responsible for managing the aquaculture sector (Utomo et al. 2021) (FAO, 2022) (Ministry of Marine Affairs and Fisheries Strategic Plan Fisheries Year 2020–2024). These two agencies are responsible for issuing permits (including waste discharge from shrimp ponds and water quality monitoring), audits, certification for IndoGAP compliance, business licensing, and compliance with marine and coastal planning (FishSource, 2023[42]) (Ministry of Marine Affairs and Fisheries Strategic Plan Fisheries Year 2020–2024). But governance is decentralized in Indonesia, so it is up to regional (i.e., provincial and regency) governments to implement national policies within the aquaculture sector; typically, regional MMAF and MoEF offices (FishSource, 2023, citing Hatfield 2018) (Utomo et al. 2021).

The following sections start from a broad perspective and lead to a more detailed evaluation of effluent regulation, because the regulatory framework governing aquaculture effluent in Indonesia exists within a larger, more complex regulatory system, which has been rapidly overhauled since 2019. To start, the Omnibus Law on Job Creation Act of 2020 is reviewed because it modifies environmental law of Indonesia, including permitting and planning, which operate within a national and provincial spatial planning scheme. Following the Job Creation Act is the "Implementation of environmental management and protection" (2021), because it updates the environmental permitting and water quality standards.

---

[42] https://www.fishsource.org/aqua_page/4

Lastly, to determine the effectiveness of this effluent management framework, ecological impacts are summarized.

National Environmental Laws

Article 28H of the 1945 Constitution of the Republic of Indonesia created a central pillar for environmental law and protection in Indonesia, stating that a good and healthy environment is a human right for every Indonesian citizen. To uphold this ideal, there are two key laws that create the basis of Indonesia's environmental legal framework: the 2009 Environmental Protection and Management Law No. 32, and its recent amendment, the Job Creation Act of 2020. The Job Creation Act is intended to relax "…Indonesia's complex web of business, labour and environmental laws in an attempt to attract investment and stimulate the economy" (Wijaya, C., 2020). This has resulted in new technical guidance and regulations for how natural resources are managed and protected, including fisheries and aquaculture.

Marine and Land Spatial Planning

To help facilitate the Job Creation Act of 2020, Implementation of Spatial Planning No.21 (2021) describes the technical process for land- and marine-based spatial management/zoning. These exhaustive planning regulations define the regulatory tradeoffs between development and environmental protections.

It is the responsibility of each province—and the respective regional planning agency—to develop a detailed development plan, with resource use zones (see Criterion 3—Habitat, Factor 3.2) determined by an ecosystem's carrying capacity. When implemented, these policies help to create a theoretical framework for area-based aquaculture zones.

Despite the existence of these legal frameworks (e.g., aquaculture zones and an ecosystem approach to aquaculture), there is little information available determining if they have been implemented (details follow); if so, where; or the ecological principles incorporated, with supplemental justification and rationale. In addition, there is no readily available information defining the carrying capacity of each ecosystem where farms exist—a key tenet that defines the limits of industry development and effluent discharge.[43] This may be a symptom of the decentralized approach to government in Indonesia.

Managing and Planning for Aquaculture

To help support the development and spatial planning legislation, there are a number of regulations and guidance forms that outline the legal framework for managing and planning for aquaculture in Indonesia within the spatial approach. Guiding all aquaculture development are broad environmental protections including (but not limited to):

- Ministerial Regulation Fisheries and Marine No. 26-2021 prevention of pollution, prevention of damage, rehabilitation and improvement of fish resources
- Implementation of environmental management and protection (2021)
- Protection and Management of the Environment. No. 32 (2009).

---

[43] The RZWP3K is discussed further in Habitat Factor 3.2, and it is recognized here that the MMAF guidance regulations (Regulation No. 23, 206 and Preparation Guidelines MMAF, 2016) may be sources for additional insight into how carrying capacity or water-quality suitability indexes were defined, but the text was not readily available. Examples were shared (pers comm Sualia, 2025) that show the results of regional water-quality indexes, but these appear to be focused on identifying areas (or zones) with water quality that is suitable for shrimp farming, rather than the prevention of impacts in zones where shrimp farming is subsequently permitted. Further research and documentation is needed.

Combined, these policies seek to protect the environment and regulate the shrimp farming industry (among others) by defining what aspects of the environment are to be protected, such as pollution prevention, damage prevention, rehabilitation, and improvement of fish resources and their environment. Regulation No. 26 (2021) describes how Indonesia manages the shrimp farming industry under the marine and fishery sector. This includes how the allocation and potential area for aquaculture is delegated to the minister/governor/regent/mayor, to determine the potential allocation for aquaculture development within their jurisdiction consistent with marine- and land-based spatial planning guidance. Also, Ministerial Regulation Fisheries and Marine No. 26-2021, "prevention of pollution, prevention of damage, rehabilitation and improvement of fish resources" describes how the shrimp farming industry (among others) must prevent pollution to fisheries resources and ecosystems from effluent, in addition to habitat impacts like mangrove degradation and escapes.

To help achieve these ideals, the guidance and standardization of environmental protections are described in Implementation of Environmental Management and Protection (2021). This critical environmental regulation implements the Job Creation Act and revokes previous related government regulations[44] (EnviX, Ltd., *no date*). Sections that are applicable to this criterion include the establishment of water quality standards for natural waterbodies, the use of a watershed and ecosystem approach to determine the allowable water pollutant load, and the determination of environmental licensing.

Environmental licensing (or permitting) is the main regulatory control for environmental protections and effluent discharge, which is evaluated through a spectrum of risk. This is generally formulated for shrimp aquaculture based on farm size—the bigger the farm, the greater the risk, and the greater the required review is for environmental compliance. For brevity, the thresholds and corresponding environmental review are summarized as follows (see Criterion 3—Habitat for more detail)[45]:

- An Environmental Impact Analysis (EIA)[46] is required if a business will have significant impacts to the environment. For shrimp farms, this is applicable for all farms ≥ 500 ha or those located within or directly adjacent to a protected forest. The relevant components of an EIA for effluent include a review of the government's spatial plan, including the carrying capacity of the environment, which must not be exceeded.
- Shrimp farms with impact less than significant—deemed as sizes ≤ 500 ha but ≥ 10 ha—require a statement of environment management efforts and environment monitoring efforts (UKL-UPL). Any perceived impacts must not exceed the carrying capacity of the environment.
- Shrimp farms < 10 ha must provide a statement of commitment to abide by environmental protections (SPPL).

Indonesia Effluent Regulations

At an area level, waterbodies are monitored by regional environmental agencies (Badan Lingkungan Hidup Daerah or BLHD) and the technical implementing units (UPT KKP) (pers comm, MMAF, 2021).

---

[44] Government Regulation No. 19 of 1999 on Marine Damage and Pollution Control, Government Regulation No. 41 of 1999 on Air Pollution Control, Government Regulation No. 82 of 2001 on Water Quality and Water Pollution Control, Government Regulation No. 27 of 2012 on Environmental Permit, Government Regulation No. 101 of 2014 on Management of Hazardous and Toxic Waste (B3)

[45] List of mandatory environmental impact analysis businesses. Ministerial Regulation Environment and Forestry No.4 (2021).

[46] Also referred to as AMDAL.

Sampling frequency is at least once per 6–12 months, with results posted on a website (pers comm, MMAF, 2021), although the sampling locations and strategy are unclear and neither the website nor its data were readily accessible.

At the farm level, water quality management is dependent on the permitting process. First, farms must be located within the designated aquaculture zones, as determined by the spatial management and regional zones locational permit, which defines the carrying capacity of waters and whether more discharge may be assimilated. The data and methodologies detailing how the carrying capacity and pollution loads are determined were not readily available. Approval then defines the type of environmental license and discharge permit. The type of environmental license is determined based on the perceived risk of the shrimp aquaculture farm, which is interpreted based upon the size of the farm (see the previous discussion on environmental licensing). The discharge permit is required, regardless of the size of the shrimp farm, in addition to an environmental review application. Each farm must have a technical and operation worthiness letter of approval for shrimp farm discharge, which must meet the technical standards for discharge. For shrimp farming, this includes but is not limited to wastewater treatment and monitoring and compliance with wastewater quality standards (details follow).

To demonstrate compliance with effluent-related regulatory requirements, such as compliance to water quality standards and the implementation of wastewater treatment (such as wastewater reservoirs),[47] all farms must be certified through the IndoGAP shrimp farming certification, CBIB. Depending on the size of the farm (large, medium, small), which correlates to the Environmental Licensing thresholds described previously, farms (medium and large) must demonstrate, by submitting documentation, that they are currently compliant with CBIB principles through the online permitting platform, OSS. Small farms must submit a statement letter to implement CBIB principles within one year on the OSS platform (pers comm Pratiwi, 2023). The Directorate General of Marine and Fisheries Resources Surveillance is tasked with implementing and enforcing the CBIB standards and requirements (pers. comm. Pratiwi, 2023).

Water Quality Standard

Source Water Quality Requirements

According to the IndoGAP shrimp farming certification, CBIB, all shrimp farms may only use source water that meets the criteria in Table 6. If the source water does not meet these criteria, it must be filtered before use in the grow-out ponds (CBIB for Shrimp in Indonesia SNI 8228-1: 2022).

Table 4: Source water quality requirements for CBIB. Source: CBIB for Shrimp in Indonesia SNI 8228-1: 2022 (National Standardization Agency (BSN), 2022)

Parameter	Unit	Mark
Biological oxygen demand (BOD)	mg/L	Maximum 20
Salinity	g/L	0.5–35.0
pH	—	7.0–8.5
Total suspended solids (TSS)	mg/L	Maximum 80
Lead (Pb)	mg/L	Maximum 0.008
Cadmium (Cd)	mg/L	Maximum 0.001
Mercury (Hg)	mg/L	Maximum 0.001

---

[47] Regulation Of The Minister Of Marine And Fisheries Concerning Standards Of Business Activities And Products On The Implementation Of Risk-Based Business Licenses In The Marine And Fishery Sector. No. 10 (2021).

Grow-Out Pond Water Quality Requirements

Grow-out ponds must also monitor water quality conditions and demonstrate compliance to the criteria defined in Table 7.

Table 5**: Grow-out pond water quality requirements for CBIB. Source: CBIB for Shrimp in Indonesia SNI 8228-1: 2022 (BSN, 2022**).

Parameter Water	Unit	Mark
Temperature	°C	23–32
Salinity	g/L	5–35
pH	—	6–8.5
Dissolved oxygen	mg/L	> 3.0
Alkalinity	mg/L	80–250
Material organic total	mg/L	≤ 100
Ammonia (NH_3–N)	mg/L	≤ 0.1

There are a number of other guidance documents[48] from various nongovernmental organization sources (e.g., UNIDO GQSP) and government documents (MMAF) with similar grow-out water quality tables, but these are all guidance to help farmers, and the conditions are not required for compliance to environmental regulations or CBIB.

Pond Effluent Discharge Water Quality Requirements

The goal of any wastewater treatment is to reduce pollution from effluent discharge into receiving waterbodies. Water quality standards help set the target for effluent treatment. The water quality standard for shrimp farm effluent are defined in the IndoGAP shrimp farming certification, CBIB, which cites the industry standard 8228-1:2022 (Table 8). The effluent limits are applicable to all shrimp farms across Indonesia, for all watersheds (pers comm, Widigdo and Kokarkin, 2024). Effluent limits may be further reduced (e.g., total suspended solids, dissolved oxygen, pH) at the provincial level, but details were not readily available. If the farm is located within a conservation area zoned as a marine biota or marine tourism area, enhanced water quality discharge limits may be necessary (Table 9).

Table 6: Pond water discharge limits. Source: CBIB for Shrimp in Indonesia, 2022.

Parameter	Unit	Mark
Biological oxygen demand (BOD)	mg/L	≤ 50
Total suspended solid (TSS)	mg/L	≤ 100
Dissolved oxygen (DO)	mg/L	≥4
pH	—	6.5–9
Total allowable nitrogen (TAN)	mg/L	≤ 5
Orthophosphate	mg/L	≤ 0.5

---

[48] SOP for *L. vannamei* cultivation, 2021 by SMART Fish Indonesia, SOP for Traditional Plus Cultivation, 2023 by SMART Fish Indonesia and Technology Cultivation Shrimp Modern and Management Supervision 2021 by MMAF.

Table 7: Water quality standard for discharge into harbor, marine tourism, and into coral, mangrove, and seagrass waters. Source: Implementation of environmental management and protection. Appendix VIIII. No. 22 (2021).

Parameter	Unit	Marine Tourism	Marine Biota
pH	—	7–8.5	7–8.5
Dissolved Oxygen	mg/L	> 5	> 5
BOD	mg/L	10	20
Ammonia	mg/l	0.02	0.3
Phosphate	mg/L	0.015	0.015
Nitrate	mg/L	0.06	0.06
Total Suspended Solids	mg/L	20	Coral: 20 Mangrove: 80 Seagrass: 20
Turbidity	NTU	5	5
Coliform (total)	Quantity/100 mL	1000	1000
Phytoplankton	Cells/ml	1000	1000
Color	Pt. Co	30	—

It is not clear how the effluent discharge limits were developed. They do not appear to be specific to waterbodies throughout Indonesia—despite the need to operate within the carrying capacity of ecosystems—and the sampling strategy is not clearly defined (e.g., do the sampling schedule/effluent limits include peak discharge periods such as harvest or pond cleaning, and/or peak biomass periods).

Environmental Monitoring

Environmental monitoring must be carried out by the business owner, with compliance to the relevant water quality standard, parameter, and thresholds. Water quality samples taken by authorities are required at the pond effluent discharge point and within the receiving waterbodies. Samples are required to be tested for chemical, physical, and biological water quality parameters consistent with the discharge standard at a government or third-party accredited lab (pers comm, Faturakhmat, MMAF, GQSP UNIDO, 2021).

The frequency of field inspections at farms varies, depending on the assigned risk and compliance history.[49] Risk is determined based on the business scale, which is defined based on the business' capital and annual sales:[50]

- Micro-business: business capital up to 1 billion Rp, annual sales up to 2 billion Rp. Risk is *Low* and initial field inspections are carried out once, and if compliant, field inspections are no longer conducted. Businesses must submit compliance to CBIB through an online portal.[51]
- Small business: business capital between 1 and 5 billion Rp, annual sales between 2 and 15 billion Rp. Risk is *Low* and initial field inspections are carried out once, and if compliant, field inspections are no longer conducted. Businesses must submit compliance to CBIB through an online portal.

---

[49] Regulation Of The Minister Of Marine And Fisheries Concerning Standards Of Business Activities And Products On The Implementation Of Risk-Based Business Licenses In The Marine And Fishery Sector. No. 10 (2021).

[50] Guidebook Simplification of Licensing Trying a Shrimp Farm, 2022 citing Government Regulation No. 7 of 2021

[51] https://oss.go.id/en

- Medium business: capital > 5 billion to 10 billion Rp., annual sales > 15–50 billion Rp. Risk is *Higher* and farms are visited twice per year and, if compliant, field inspections are carried out once per year thereafter. Businesses must submit compliance to CBIB through an online portal.
- Large business: business capital attributes were not defined. Risk is *Higher* and farms are visited twice per year and, if compliant, field inspections are carried out once per year thereafter. Businesses must submit compliance to CBIB through an online portal.

According to the water quality standard, penalties for noncompliance depend on the type and severity. If operating without a business license/environmental approval and there are resulting environmental damages, the operator may face criminal penalties (Utomo et al. 2021):

- 1–3 yrs imprisonment
- IDR1–3 billion fine (USD64,669–194,000[52])

Other breaches of environmental approval may result in administrative sanctions (Ministerial Regulation Fisheries and Marine No.31-2021 Determination of Administrative Sanctions) (pers comm, GQSP, CPP, MMAF, 2021):

- Written warning
- Temporary suspension of production activities
- Suspension of business license and/or fine
- Revocation of business license
- Possible imprisonment

National Standards: IndoGAP CBIB

Indonesia has a series of National Standards—referred to as SNI—and many for aquaculture, including *P. monodon* and *L. vannamei* shrimp production throughout the value chain. The complexity of the numerous SNI standards and the resulting inefficiencies, challenges of implementation, and misalignment with international standards or regulations has spurred movement toward one standard—IndoGAP—by the lead agencies: MMAF and the National Standardization Agency (Badan Standardisasi Nasional—BSN) (UNIDO, 2020). According to the Ministry of Marine Affairs and Fisheries Strategic Plan Fisheries Year 2020–2024, published in 2020, "the implementation of good aquaculture practices (IndoGAP) has not yet been implemented optimally in the implementation of aquaculture activities." Despite these technical challenges of implementation and enforcement, it appears to be a helpful step to organize the industry and set transparent standards. The numerous governmental and nongovernmental agencies working to help address the design and implementation challenges of IndoGAP CBIB must be commended for their diligent work in this space, because it is a complex task.

To obtain IndoGAP certification, an initial application is needed with documentation demonstrating compliance to the IndoGAP standard—in addition to a site inspection. Approval results in certification that lasts for 4 years, with a follow-up site visit every 2 years (Regulation Of The Minister Of Marine And Fisheries Concerning Standards Of Business Activities And Products On The Implementation Of Risk-Based Business Licenses In The Marine And Fishery Sector. No. 10, 2021). If there are any infractions during an inspection, the farm has 6 months to correct. Failure to correct within this period or at all, results in the loss of certification (Technical instructions of product certification scheme, Indonesian good aquaculture practices [IndoGap] Part 1: How to share good fish (CPIB) and/or good fish cultivation (CBIB). Appendix IV, 14, 2019). IndoGAP certification may be pursued for individual farms and groups of

---

[52] Using IDR to USD exchange rates on August 27, 2024.

farms so long as the group comprises cultivation units with adjacent boundaries, is legally considered a "group," and managed as a single enterprise, including biosecurity plans (Technical instructions of product certification scheme, Indonesian good aquaculture practices [IndoGap] Part 1: How to share good fish (CPIB) and/or good fish cultivation (CBIB). Appendix IV, 14, 2019). It appears, though not corroborated, that businesses that have been IndoGAP certified are listed on the CBIB website (as of June 2024, there are 28 *L. vannamei* farms listed[59]).

Evidence of Effluent Impacts

In theory, Indonesia's spatial management legislation and directive to identify and develop within the carrying capacity of the environment both exemplify key sustainable development ideas—cumulative impact and area-based management. Despite these recent efforts, there appear to be systemic gaps in the acting effluent regulations. Although there are new or updated water quality standards for shrimp farms discharging into the environment (see Table 8), information was not readily developed to detail how it was developed. They do not appear to be specific to waterbodies throughout Indonesia—despite the need to operate within the carrying capacity of ecosystems. In addition, the implementation of sediment ponds and reservoirs, though required, seems to be challenging for farmers, while its enforcement appears lacking.

Because the farm-level water quality discharge appears to have minimal ecological considerations, previous findings connected to prior legislation appear relevant. For example, unclear and continually evolving regulations led to poor coordination between the national and regional governments across many levels of administration (Ministry of Marine Affairs and Fisheries Strategic Plan Fisheries Year 2020-2024) (Tortora, P. and Agnelli, A., 2019). The resulting environmental externalities (from all industries) include pollution of the environment and aquatic resources, which caused a decline in coastal water quality (Adyasari, et al. 2021 and citations therein) (Ministry of Environment, 2016). Further, there do not appear to be readily available public portals measuring or documenting coastal water quality (e.g., the status of water quality of an area or the results of farm monitoring discharge). The lack of publicly available data on coastal water quality exacerbates the concern about the reporting of excessive nutrients, heavy metals, and organic matter from point sources and nonpoint sources overwhelming watersheds (Adyasari, et al. 2021) (Asian Development Bank, 2016). In a review of anthropogenic pollutant studies in Indonesia from 1986 to 2021, Adyasari et al. (2021) found that 82% of the studies showed "nutrient concentrations exceeding the standard limits, compared to heavy metals (54%) or organic pollutants (50%)." Aquaculture is an important source of nutrient pollution (Asian Development Bank, 2016), and shrimp aquaculture in particular is significant due to a lack of wastewater treatment, which has exacerbated coastal pollution (Royan, M. 2020 and citations therein). This has led to public complaints about the shrimp farming industry because of ineffective environmental quality standards, exceedance of carrying capacities, and inappropriate disposal of waste (Technical instructions wastewater treatment for vannamei shrimp, Marine and Fisheries Ministry Directorate General of Cultivation Fisheries, 2019) (Technical guidelines for the management of aquaculture areas with an ecosystem approach, YEAR—doc 72). The resulting impact is correlated with harmful algal blooms, coastal eutrophication, and/or hypoxia (see Criterion 3—Habitat, Factor 3.1 for more details on ecological impact to marine ecosystems) (Royan, M. 2020) (Adyasari, et al. 2021). This is alarming, considering the connectivity between coastal shrimp ponds and critical marine ecosystems for marine biodiversity (i.e., coral reefs, seagrass, mangroves).

---

[59] https://cbib.kkp.go.id/data-cbib

Therefore, despite the recent changes to the national legislation, there does not appear to be any acting regulatory change to shrimp farming effluent discharge, and there is an apparent gap between the legislative ideals and the acting regulations. As a result, from the evidence described in the literature, it appears that the content of the regulations and management measures has not prevented shrimp farms from contributing to the degradation of aquatic ecosystems. And, despite recent legislative changes that incorporate more of an area-based framework, further revisions to acting legislation and implementing regulations are apparently needed to close the gap between policy (legislation) and practice (regulations). It must also be noted that many of the effluent legislation and regulations described have been constructed recently (< 2 years), and it may be that time is needed to materialize environmental benefits and to implement changes across the many provinces and farms.

Factor 2.2a—Conclusion

The new legislative framework for natural resource management, which covers shrimp farming, is an area-based, cumulative management system; however, the regulations for shrimp farming effluent management are limited. There are spatial management plans that set a goal of an area-based, cumulative management framework, but the integration of aquaculture with other industries appears to be lacking. Besides siting, wastewater treatment and water quality standards are core ecological principles to regulate and limit effluent pollution within the carrying capacity of receiving waters. Despite updated water quality discharge limits for shrimp farms, there is no readily available evidence to suggest that these limits are prescriptive to the various waterways, locations, and ecosystems of Indonesia. There are new requirements for sedimentation ponds, which may help to reduce the evidence of coastal degradation (with shrimp aquaculture as a significant source), but their implementation appears lacking. Overall, the management system does appear to set effluent limits, but there is no evidence to suggest that effluent discharge limits are set to minimize area-based or cumulative-level impacts. The score for Criterion 2—Effluent, Factor 2.2a is 3 out of 5.

Factor 2.2b—Enforcement of effluent management measures

The main mechanism for evaluating and enforcing shrimp farm compliance to environmental standards, such as effluent discharge, is through permitting, audits and inspections, and imposing sanctions (i.e., penalties) (Utomo et al. 2021). As described in Factor 2.2a, the Ministry of Marine Affairs and Fisheries (MMAF) and the Directorate General of Aquaculture are the primary enforcement authorities and oversee the technical implementation unit—Brackishwater Aquaculture Center, UPT, and the Directorate of Surveillance and Control of Marine and Fishery Resources (PSDKP), along with other divisions. The Ministry of Environment and Forestry (MoEF) is also a leading authority on enforcing environmental compliance, but effluent monitoring is carried out by several different divisions of MMAF: the local Environmental Office, Aquaculture Technical Implementation Unit, the local Fisheries Office, or an auditor from certification institutes (pers comm, MMAF, GQSP UNIDO, Faturakhmat, 2021). Further insights were not readily available about the location, number of employees, and other statistics regarding the capacity of MMAF and local agencies tasked with enforcing environmental compliance to the shrimp farming industry.

Inspections do appear to occur. The number of visits to farms is reportedly consistent with the regulatory requirements, according to reports from shrimp farming stakeholders (pers comm, MMAF, Faturakhmat, and CPP, 2021). But as stated in Factor 2.2a, the required frequency of farm visits is dependent on the size of the farm and its compliance history; so, technically, the annual required field inspections can be zero (for micro- and small farms) or one (for medium and large farms).

The results of all environmental inspections are submitted on the online single submission (OSS) government portal,[62] which seeks to provide a comprehensive regulatory platform and storage of documents and permits accessible by farmers.[63] But the results of inspections do not appear to be publicly available, and according to Utomo et al. (2021), although public information registers are available on the environmental agency website of each Indonesian regency or province, there is disparity in the level of information available. This apparent intent to make data publicly available, combined with an apparent lack of ability to access it in practice, occur consistently.

There does not appear to be any readily available information detailing evidence of shrimp farms operating in compliance or noncompliance with effluent discharge. Also, data describing the location or sampling frequency of receiving waterbodies near shrimp farms could not be found. Similarly, there is no readily available information demonstrating IndoGAP enforcement, penalties for infringement, or compliance rates. According to the MMAF (2019), there have been public complaints of environmental pollution (inclusive of water quality) caused by noncompliant shrimp farms, yet there were no further details available (Technical guidelines for the management of aquaculture areas with an ecosystem approach. No. 154/Per-DJPB, 2019). As noted in Factor 2.2a, since 2019, national legislation has changed to a more ecosystem-based approach to aquaculture, but how or if this has changed enforcement resources is unknown.

Factor 2.2b—Conclusion

Enforcement of effluent management measures appears to be limited. The agencies enforcing effluent limits are active, but they may have limitations in resources. The intended frequency of farm visits depends on the size of the farm and the compliance history; however, data demonstrating enforcement of these inspections are lacking, and the inconsistency of inspections and the lack of identifiable strategy limit the potential enforcement effectiveness. There is considered to be area-level monitoring of waterbodies, but the adaptive management and enforcement principles—such as feedback loops between monitoring noncompliance results and enforcement "upstream" to point or nonpoint sources of shrimp farms—appear to be missing. Importantly, public evidence of compliance and monitoring data is not mandatory, is published inconsistently, and is apparently not readily available. As a result, enforcement measures and monitoring and compliance data are considered limited. The score for Criterion 2—Effluent, Factor 2.2b is 2 out of 5. Combined, Factors 2.2a and 2.2b score 2.4 out of 10 for Factor 2.2—management of farm-level and cumulative impacts.

Conclusions and Final Score

In unfed extensive *P. monodon* and *L. vannamei* shrimp farms, fertilizer application is the primary nutrient input that may pollute surrounding waterbodies if discharged in effluent. Although data are limited, it was estimated that 80 kg/ha of inorganic fertilizer (urea) is used, and with low shrimp yields per hectare (i.e., low nutrient outputs in harvested shrimp), the estimated net nitrogen in soluble and particulate waste is 39.95 kg N per MT of *P. monodon* and 41.71 kg N per MT of *L. vannamei* production in extensive systems. In fed *L. vannamei* semi-intensive and intensive systems, feed and fertilizer represent the primary nutrient inputs. For *L. vannamei* grown in intensive ponds (with an estimated feed protein content of 33.6%, an eFCR of 1.4, and urea fertilizer use of 0.6 kg N per MT of shrimp production), the resulting waste production is 47.38 kg N per ton of *L. vannamei.* In semi-intensive systems (with an estimated feed protein content of 33.6%, an eFCR of 1.4, and fertilizer use of 2.58 kg N

---

[62] Regulation Of The Minister Of Marine And Fisheries Concerning Standards Of Business Activities And Products On The Implementation Of Risk-Based Business Licenses In The Marine And Fishery Sector. No. 10 (2021).

[63] https://oss.go.id/en

per MT of shrimp production), the resulting waste production is 49.36 kg N per ton of *L. vannamei.* Considering the nutrient dynamics in ponds in addition to the typical water exchange rates, water treatment, and the collection and appropriate disposal of sludge (although varying between production systems), 18% of the waste N produced is considered to be discharged from extensive systems, resulting in a score for Factor 2.1—waste discharge of 9 out of 10 for *L. vannamei* and *P. monodon.* For semi-intensive and intensive systems growing *L. vannamei,* 27% of the waste N produced is considered to be discharged, resulting in a score of 8 out of 10.

Indonesia has a new legislative framework for natural resource management, which covers shrimp farming, and is intended to be an area-based, cumulative management system. There are also provincial/subnational spatial management plans that set a goal of an area-based and cumulative management framework; however, the necessary integration of aquaculture with other socioeconomic industries appears to be lacking. Wastewater treatment and water quality standards are additional core ecological principles to regulate and limit effluent pollution within the carrying capacity of receiving waters; despite updated water quality discharge limits for shrimp farms, there is no readily available evidence to suggest that these limits are prescriptive to the various waterways, locations, and ecosystems into which shrimp farms discharge effluent in Indonesia. There are new requirements for sedimentation ponds, which may help to reduce the evidence of coastal degradation (with shrimp aquaculture wastewater as a significant source), but their implementation appears to be lacking. Overall, the management system does appear to set effluent discharge limits, but there is no evidence to suggest that they are set to minimize area-based or cumulative-level impacts. The score for Criterion 2—Effluent, Factor 2.2a is a moderate 3 out of 5.

Enforcement of effluent management measures appears to be limited. The agencies enforcing effluent limits are active, but they may have limitations in resources. The intended frequency of farm visits depends on the size of the farm and the compliance history. Data demonstrating enforcement of these inspections are lacking, and the inconsistency of inspections and the lack of identifiable strategy limit the potential enforcement effectiveness. There is considered to be area-level monitoring of waterbodies, but the adaptive management and enforcement principles—such as feedback loops between monitoring noncompliance at the area level and enforcement “upstream” to point or nonpoint sources of shrimp farms—appear to be missing. Importantly, public evidence of compliance and monitoring data is not mandatory, is published inconsistently, and is apparently not readily available. As a result, enforcement measures and monitoring and compliance data are considered limited. The score for Criterion 2—Effluent, Factor 2.2b is 2 out of 5 and is applied to all species and systems.

Combining all factors results in the following Criterion 2—Effluent scores:

- *L. vannamei* intensive, 6 out of 10
- *L. vannamei* semi-intensive, 6 out of 10
- *P. monodon* extensive, 7 out of 10
- *L. vannamei* extensive, 7 out of 10.

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: being located at sites, scales and intensities that maintain the functionality of ecologically valuable habitats.

Criterion 3 Summary—All Production Systems

	***L. vannamei* and *P. monodon* Farms**	
Habitat parameters	**Value**	**Score**
Intensive, Semi-Intensive and Extensive *L. vannamei*		
F3.1 Habitat conversion and function		4
Extensive *P. monodon*		
F3.1 Habitat conversion and function		3
All production systems		
F3.2a Content of habitat regulations	2	
F3.2b Enforcement of habitat regulations	1	
F3.2 Regulatory or management effectiveness score		0.8
Intensive, Semi-Intensive and Extensive *L. vannamei* C3 Habitat Final Score (0–10)	**2.93**	
Extensive *P. monodon* C3 Habitat Final Score (0–10)	**2.27**	

Brief Summary

The conversion of mangroves or wetlands to aquaculture ponds is considered to result in a loss of the important ecosystem services typically associated with those habitat types. Nearly 1 million hectares, or 22%, of Indonesia's total mangrove forest area were deforested from 1800 to 2012, and for major shrimp producing islands, nearly half of their historical total mangroves have been lost (≈49% or ≈1.3 million hectares total from 1800 to 2022, or 73% loss on Java, 54% on Sulawesi, 39% on Kalimantan, and 30% on Sumatra). Noting that there is some uncertainty in the scale of shrimp farming's role in this long-term mangrove land-use change, the general literature does indicate that the mangrove forests of these islands have been majorly affected by their conversion to shrimp farms. By comparing the total shrimp pond area in 1999 and 2022, it appears that roughly two-thirds of the pond area present in 2022 was developed before 1999 (with some exceptions), which sets an important baseline for this assessment. The most recent data available (2020–22) indicate that there is still ongoing conversion of mangroves within each of the significant shrimp farming areas—Kalimantan, Java, Sulawesi, and Sumatra—although the most recent data show that the rate of conversion between 2020 and 2022 has declined for all regions. Altogether, there is a complex pattern of habitat conversion across the islands, species farmed, and timeframes, but by considering the characteristics of each island group and the dominant species produced, some distinctions can be made:

- The typical or average shrimp farm in Kalimantan is considered to have been built in high-value habitats such as mangroves or wetlands relatively recently (after 1999), and there is evidence of recent or ongoing conversion. The score for Factor 3.1 for Kalimantan is 0 out of 10. Harvest data indicate that nearly one-third of Indonesia's *P. monodon* is produced on Kalimantan, with no significant *L. vannamei* production.
- For the other islands, the typical or average shrimp farm is also considered to have been built in high-value habitats, on a precautionary basis, but mostly before 1999 (Java: 98%; Sulawesi: 85%; Sumatra: 90%;, and the Lesser Sunda Islands: 90%). The score for these islands is 4 out of 10. The island harvest figures indicate that both species are produced to varying degrees on these islands, but *L. vannamei* is dominant.

By considering the different species' production characteristics across the main island groups, a weighted score for Factor 3.1 for each species can be determined that more closely reflects the associated habitat conversions across Indonesia. As a result, the weighted island/species scores across Indonesia for Factor 3.1 are 3 out of 10 for *P. monodon* and 4 out of 10 for *L. vannamei*.

Current habitat management measures that define the recent and ongoing development of shrimp farming in Indonesia are based on ecological principles, yet appear to be limited in their implementation. It is up to each province—and the respective regional planning agency (BAPPEDA)—to develop a detailed development plan, with resource use zones determined by an ecosystem's carrying capacity as reflected in the RZWP3K—Zoning Plan for Coastal Areas and Small Islands. But even though aquaculture zones have been defined, there is no readily available information demonstrating that an effective carrying-capacity study has been defined or implemented (i.e., supportive regulation/guidance). Without a transparent and justified spatial management plan, important management principles such as cumulative impacts and habitat connectivity do not appear to be incorporated. Farm siting within aquaculture zones requires a permit and/or license, for which the associated environmental review and its rigor is dependent on the size of the planned farm, but it is unclear what habitat protections are mandated through this process (if any) for any size of farm. Presidential Decrees No. 32 of 1990 and No. 51 of 2016 state that aquaculture farms cannot be sited within a green belt (100 m from the coast and 50 m from inland waterways), in order to act as a buffer for mangrove forests, but evidence suggests that these decrees are not effectively enforced in the farm siting process. There have been substantial conservation efforts to protect and replant mangroves in Indonesia, which have had some success, but they have fallen short of lofty goals and expectations. Overall, the content of the habitat management framework is considered to lack a clear demonstration of the practical measures necessary to effectively achieve the ecological principles underpinning sustainable aquaculture, carrying capacity, and cumulative management. As a result, the content of habitat management measures is limited, and Factor 3.2a—content of habitat regulations scores 2 out of 5.

There are numerous national and provincial agencies charged with managing shrimp farm siting and mangrove protections, but there is a clear pattern (as detailed in Factor 3.1) of ongoing land-use change of mangroves to brackish-water ponds on every island where there is significant pond area. The siting of shrimp farms in aquaculture zones and outside mangrove greenbelts is enforced through permit applications and field audit visits, but compliance rates are unknown, and there is some evidence to suggest that enforcement of these regulations is minimal (one report of illegal clearance and encroachment of mangrove forests was found, but it is not known if this is an isolated occurrence). The ongoing conversion may be due to the differing scopes of management agencies and national goals, which creates challenges for the government to enforce mangrove protections and farm siting effectively and consistently across Indonesia. Restoration remains an ongoing priority, with some success. Altogether, it appears that enforcement organization and their activities are difficult to identify, with little evidence of monitoring or compliance data and limited evidence of penalties for infringements. As a result, the Factor 3.2b—enforcement of habitat regulations score is 1 out of 5. Therefore, the overall effectiveness of the management system (for all production systems) is considered to be limited, and the score for Factor 3.2—regulatory or management effectiveness (combining Factors 3.2a and 3.2b) is 0.8 out of 10.

Combining Factors 3.1 and 3.2 results in the following scores for Criterion 3—Habitat:

- *L. vannamei* intensive is 2.93 out of 10
- *L. vannamei* semi-intensive is 2.93 out of 10
- *L. vannamei* extensive is 2.93 out of 10
- *P. monodon* extensive is 2.27 out of 10.

Justification of Rating

The Habitat Criterion comprises two factors: Factor 3.1—Habitat Conversion and Function, and Factor 3.2—Farm Siting Management Effectiveness. Factor 3.1 estimates the impact of habitat conversion to aquaculture in terms of ecosystem function by using indicators for assessing changes in the provision of ecosystem services. While Factor 3.1 assesses the impact of habitat conversion and function from shrimp farms at the region or industry level, Factor 3.2 deals with the existence and enforcement of management and regulations that govern the expansion and cumulative impact of the industry as a whole.

As discussed further, all the production systems assessed in this report have affected mangrove forests to varying degrees and at varying times. Given the ecological value of mangroves and other wetlands, there is a considerable amount of data on the changing dynamics of these habitats, including geographically by island across Indonesia. But breaking down the impact to these habitats by the different production systems remains challenging, because the relevant data are limited. Nevertheless, there are enough granular data to score each species under scope for Factor 3.1, while the scores for Factor 3.2 are for all species and production systems under scope.

Factor 3.1—Habitat conversion and function

Data Availability/Sources

Indonesia is a complex territory of 16,056 islands (with 4 main islands and 4 archipelagos) covering nearly 2 million km^2 (1,916,906 km^2 or 740,121 mi^2).[66] To help understand the historical timeline and development of the shrimp farming industry as a whole, numerous academic studies were reviewed and presented here to help provide a holistic timeline of events (e.g., Villamoor et al., 2015; Pagiola, 2000; Ilman, 2016; and Aslan et al., 2021), but they are typically spatially, contextually, or temporally limited in scope, with differing findings likely the result of the evolution of geospatial methodology (Rahardian et al. 2019).

---

[66] https://www.eyeonasia.gov.sg/asean-countries/know/overview-of-asean-countries/indonesia-a-country-profile/

In contrast, the interactive online map, "Coastal Habitat Mapping: Mangrove and Pond Aquaculture Conversion" from Clark Labs[67] (developed in partnership with the Gordon and Betty Moore Foundation) is a comprehensive, publicly available resource providing land-cover and land-use change data for more recent years (1999 to 2022). The focus of this tool is on brackish-water aquaculture ponds broadly and allows for categorical and temporal review of land-use change by location and habitat type (i.e., mangrove forests and wetlands). According to data from the Clark Labs (discussed further), Indonesia had a total of 8,355.461 km^2 of coastal brackish-water aquaculture ponds in 2022, which are considered to produce a variety of species.[68] According to data obtained from Aquascape Longline Environment (pers comm, Anonymous, 2021), in 2021, there were 95,400 shrimp farms that comprised 497,506 shrimp ponds with a total area of 6,864.0 km^2 (686,400 ha). By comparing these values, it can be seen that shrimp ponds account for approximately 80% of the total brackish-water pond area. In addition, some of the ponds currently used for other species, such as milkfish, were initially constructed for shrimp but later abandoned as disease problems reduced shrimp production (pers comm, Larson, S., University of the Sunshine Coast, March 2023). Therefore, overall, the land-cover and land-change data relating to brackish-water ponds from Clark Labs are considered to be a suitable proxy for the development of shrimp ponds in Indonesia and are used extensively in this factor.

Mangrove area estimates are primarily from Clark Labs, while Indonesia's National Mangrove Map (MMAF, 2021b) is also referenced for the year 2021. In comparing the two sources, the range of the total mangrove coverage estimates from the National Mangrove Map of 2021 by MMAF and Clark Labs' 2022 are likely due to differences in remote sensing methodology, along with misalignment in defining mangrove forests (Jong, 2023).

The data describing production (metric tons, MT) by species and location in 2022 are from the Statistik-KKP[69] data portal (see Table 2 in the Introduction). More recent data do not appear to be readily available. Statistik-KKP also provides data on the production area by province and production system type[70] (see Table 3 in the Introduction). Although these data are useful, there are no metadata describing the methodology or context of the pond area (e.g., the intensity of production), which limits their application. When comparing island area totals between Clark Labs and Statistik-KKP, they do not align, and there is not a clear pattern to explain the difference. It is considered here that this may be due to differences in the land area accounting methods or pond area definitions between the two geospatial analyses. There also appears to be a significant outlier in the KKP dataset: Sulawesi Utara has an estimated 154,445 ha of extensive pond area in 2022, while Clark Labs estimates just 454 ha of ponds in 2022. In general, Clark Labs overestimates the land area versus Statistik-KKP, except for Sulawesi, which helps to offset the total pond results. For example, the difference in the total pond area between Clark Labs and Statistik KKP for all of Indonesia is relatively small (13,101 ha), but by island, the range is quite large. When comparing just the islands of Java, Kalimantan, and Sumatra, the average difference is 51,326 ha, while including Sulawesi, the difference is 73,434 ha. Therefore, considering the lack of metadata and the uncertainty in the Statistik-KKP land area estimates, Clark Labs is the primary data source used in Factor 3.1.

---

[67] Coastal Habitat Mapping: Mangrove and Pond Aquaculture Conversion - Clark Labs

[68] FAO harvest data for brackish-water aquaculture in Indonesia show shrimp, milkfish, *Gracilaria* seaweed, and tilapia (FishstatJ database).

[69] https://statistik.kkp.go.id/home.php?m=prod_ikan_prov&i=2

[70] https://statistik.kkp.go.id/home.php?m=luaslahan&i=7

It should be noted that a baseline of mangrove area in 1800 for just the Lesser Sunda Islands was not available in Ilman et al. (2016) and, given the relatively small total pond area in the Lesser Sunda Islands, they are excluded from the land-use change analysis sections and figures that follow. But the Lesser Sunda Islands are a significant producer of *L. vannamei*, despite the small pond area footprint. Therefore, an analysis is provided in the footnote,[71] and will be revisited in the Factor 3.1 Scoring Analysis.

Land Use Change

The conversion of mangroves or wetlands to aquaculture ponds is considered to result in a loss of the ecosystem services typically associated with those habitat types. The Seafood Watch Aquaculture Standard considers the timeframe of the conversion of such high-value habitats, i.e., before or after 1999,[72] in addition to whether such impacts are ongoing. So, importantly, this section reviews the historical development of the industry, the habitat type converted, the regional/island conversion characteristics, and the resulting functionality of the ecosystem(s), to help put into context the more recent (post-1999) and current trends of the shrimp farming industry where possible.

Farming of shrimp and other brackish-water species in simple ponds began in Indonesia as early as the 15th century and was associated with subsistence and food security (Rimmer et al., 2013). Ilman et al. (2016) referencing Raffles (1817) note that ponds were widespread along the coasts of Java in the early 1800s and had been built in coastal mangrove forests. A transition to commercial shrimp production began in the mid-1960s, with a rapid increase in pond construction in mangroves occurring particularly after 1980 (Poernomo, 2004). Areas of initial commercial shrimp development were focused along the coastal areas of Sumatra (e.g., Aceh, Lampung), Java (e.g., Central Java, East Java), Sulawesi (e.g., South Sulawesi), Bali, and Nusa Tenggara Barat, and later expansion on the island of Kalimantan, all before 1984 (Sari, I., 2015). Ilman et al. (2016) also note that these booms in pond construction occurred toward the end of (or after) a long period of intensive mangrove forestry for timber products from 1900 to 1990.

Although all these changes in mangrove area are not directly attributed to shrimp farming, Ilman M., et al. (2016 and citations therein) estimate that nearly 1 million hectares, or 22%, of the total mangrove forest area were deforested from 1800 to 2012 (Table 10). Clark Labs data from 1999, 2014, 2018, 2020, and 2022 further illustrate the reduction of coverage by island through time, which is largely corroborated by MMAF (2021) mangrove coverage estimates in 2021 (see the preceding Data Availability/Sources section about the discrepancy). Altogether, the three separate sources—Ilman M., et al. (2016 and citations therein), Clark Labs, and MMAF (2021)—find that the total coverage of mangroves from 1800 to 2012, 2021, and 2022 has been reduced by about 1 million hectares; although the distribution by island is significantly different for some islands (i.e., Kalimantan and Sumatra). In the

---

[71] The total pond area for all of the Lesser Sunda Islands in 1999 is 8,348 ha, and the total in 2022 is 9,245 ha; an increase of 897 ha. Further, the land-use change of mangrove and wetlands to ponds from 1999 to 2022 was 1,077 ha, indicating relatively minor conversion. Therefore, on a precautionary basis, it is assumed that the mangrove ecosystems in the Lesser Sunda Islands were majorly affected before 1999—consistent with other islands and regions—and with only 10% of pond area established after 1999, it is assumed that 90% of the farms were established before 1999.

[72] See the Aquaculture Standard for the full rationale behind this date relating to the Ramsar Convention and the international recognition of the importance of mangroves and other wetlands. Indonesia had previously ratified the Ramsar Convention in 1991.

Table 8: Estimated changes of mangrove area in major mangrove regions of Indonesia. Sources: Ilman, M, et al., 2016 for years 1800 and 2012 and citations therein; Clark Labs for years 1999, 2014, 2018, 2020, 2022; MMAF National Mangrove Map for year 2021b.

	Mangrove Area Coverage by Year								**Change from 1800 to 2022**
Region	**1800**	**1999**	**2012**	**2014**	**2018**	**2020**	**2021**	**2022**	
Java	173,000	33,179	45,000	45,215	47,069	47,352	54,060	47,297	(73%)
Sulawesi	273,000	151,834	165,000	132,255	127,029	125,438	136,184	124,733	(54%)
Kalimantan	945,000	758,757	595,000	640,797	620,395	618,711	688,025	576,615	(39%)
Sumatra	860,000	633,837	600,000	631,178	621,064	610,491	531,327	605,476	(30%)
Papua	1,650,000	1,429,802	1,600,000	1,474,997	1,482,122	1,483,361	1,538,239	1,483,784	(10%)
Total	3,901,000	3,007,409	3,005,000	2,924,442	2,897,679	2,885,352	2,947,835	2,837,905	(27%)

more recent timeframe, deforestation has continued, as evidenced by the decline of mangrove forests from 1999 to 2022, and may be ongoing. There is a general trend or correlation between mangrove loss and the islands where initial commercial shrimp development was focused (Java, Sumatra, Sulawesi, and Kalimantan). If evaluating just these major shrimp producing islands, nearly 896,878 hectares of mangroves have been lost (≈40%) from 1800 to 2022. This can be compared to the large area of Papua's mangroves (see Table 10), which had the smallest percentage loss, and (in support of this correlation) also have a quite small scale of shrimp production[73] (see Tables 2 and 3 in the Introduction). Clearly, the extent of mangrove deforestation (from all causes) is significant and suggests that mangrove forest habitats in Indonesia have been majorly affected, especially across these major shrimp farming islands.

Yet it is challenging to robustly determine the historical attribution to aquaculture, beyond a simple observable correlation. Estimates of historical mangrove loss due to aquaculture pond construction vary widely. For example, Ilman et al. (2016) consider that brackish-water pond development has been the most damaging and widespread activity contributing to the loss of mangroves since 1800 in Indonesia, and the peak rate of conversion occurred between 1970 and 2003. Fawzi and Husna (2021) and Aslan et al. (2021) consider that 80% of the habitat conversion of mangrove forests in Indonesia is used for aquaculture (referencing Hamilton, 2013). But stating that these areas are "used for aquaculture" highlights a challenge in interpreting these data; that is, while aquaculture ponds have undoubtedly been built in mangrove areas and resulted in their direct loss, ponds have also been constructed in mangrove areas that had previously been cleared during timber harvesting or other activities such as agriculture. Highlighting this challenge and to account for the potential differing motivations for initial mangrove clearance, Boyd et al. (2021) consider that only 12% of Indonesia's mangrove loss (up to 2014) was due to shrimp pond aquaculture development. But, for the purposes of this assessment and determining the burdens for mangrove deforestation, the simple harvesting of mangrove trees for timber allows a relatively rapid recovery of ecosystem services compared to the more invasive excavation for ponds. Therefore, given the option to allow the recovery of deforested areas, or allow their ongoing conversion to shrimp ponds, the decisions to construct shrimp ponds is considered here to effectively be the same as primary mangrove conversion.

---

[73] It is also noted here that Papua may not have suffered other intensive exploitation of mangroves, such as commercial logging.

To conclude, historical mangrove forest loss across Indonesia has been substantial. There is a clear correlation between initial shrimp farming islands and a reduction of mangrove coverage from 1800 to 2022—73% of the historical mangrove coverage on Java has been lost, 54% on Sulawesi, 39% on Kalimantan, and 30% on Sumatra. Although there is not a robust consensus, the general literature does attribute shrimp farming as a contributing driver historically to mangrove deforestation. As a result, it appears that the mangrove forests of these islands have been majorly affected, at least in part, by their conversion to shrimp farms. But, important to this assessment is understanding when the majority of mangrove forests were converted to shrimp farms (i.e., pre- or post-1999, or potentially ongoing).

To help answer this key reference point, two sources of data have been used: Sari (2015) and Clark Labs. At a country level, Figure 2 shows that the total area of brackish-water ponds increased from approximately 250,000 ha in 1989 to about 566,000 ha in 1999, and then to approximately 835,000 ha in 2022. Therefore, it appears that more than two-thirds of the pond development occurred before the year 2000 (i.e., the pond area in 1999 is ≈68% of that in 2022), which is a helpful baseline for this assessment. After 1999, pond area has increased every year up to 2022, but the growth rate has slowed from an annual ≈3% from 1999 to 2014 to < 1% from 2014 to 2022, suggesting a stabilized trend.[74] Growth was primarily driven in the regions of Kalimantan and Sulawesi from 1999 to 2014, where the annual growth rate was ≈10% and ≈3%, respectively (all other regions and all other annual growth rates were at or below 1% except for Kalimantan from 2014 to 2018). Yet, simply evaluating the total pond

Figure 2: Brackish-water pond area in Indonesia from 1989 to 2020. One square km = 100 ha. 1989 value from Sari (2015) and 1999 to 2020 from Clark Labs.

---

[74] Note that, although the total pond area has stabilized, the total production has continued to increase due to increasing intensification; i.e., growing more shrimp in the same pond area using higher stocking densities, added feed, and other inputs such as mechanical aeration.

area can mask any potential abandonment of existing ponds and new conversion of mangrove area, which can be further evaluated by looking at each shrimp farming island and reviewing any land-use change and habitat type converted since 1999, using the Clark Lab data set.

As of 2022, the islands/regions with the largest brackish-water pond area are Kalimantan, Java, Sulawesi, and Sumatra (Figure 3). Altogether, these four areas account for 98.7% of Indonesia's total pond area in 2022, according to the Clark Labs data. The type of habitat or land-use change from 1999 to 2022 for each of these islands is shown in Figure 4 (note that conversions *to* ponds are shown as positive values,[75] and conversions *from* ponds are shown as negative values). These data show that the island of Kalimantan had by far the largest conversion of mangroves and wetlands to ponds (163,062 ha, between 1999 and 2022). Java had the least, but still converted 4,489 ha of mangroves and wetlands to ponds in the same period.

For each island, regions with the most significant mangrove and wetland conversion to ponds since 1999 are highlighted in Table 11. The island of Kalimantan is experiencing significant conversion, primarily in Kalimantan Utara and Kalimantan Timur. Sulawesi has a fairly even spread of conversion across the provinces of Sulawesi Selatan, Sulawesi Tenggara, and Gorontalo. The provinces of Sumatra Selatan and Aceh are the leading regions of conversion in Sumatra, while Jawa Barat is the most significant area for the island of Java.

To summarize the various graphs presented of land-use change type by island since 1999, Table 12 shows the total area of ponds in 2022, the area of mangroves and wetlands (i.e., high-value habitats) converted to ponds between 1999 and 2022, and the percentage of the total area that was converted from high-value habitats after 1999. These percentage values range from 2% (Java) to more than half

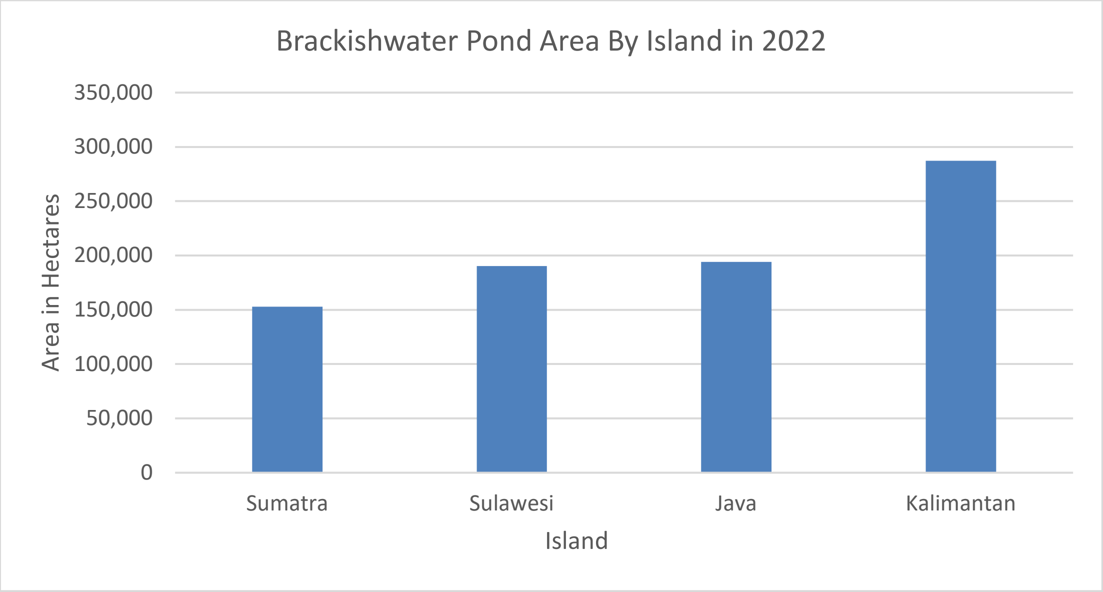

Figure 3: Distribution of brackish-water pond area (hectares) across the main island groups of Indonesia in 2022, which represents ≈98.7% of pond area in Indonesia. Data from Clark Labs.

---

[75] Note also that the "Mangrove -> other" category (yellow) is included as a positive value in the graph.

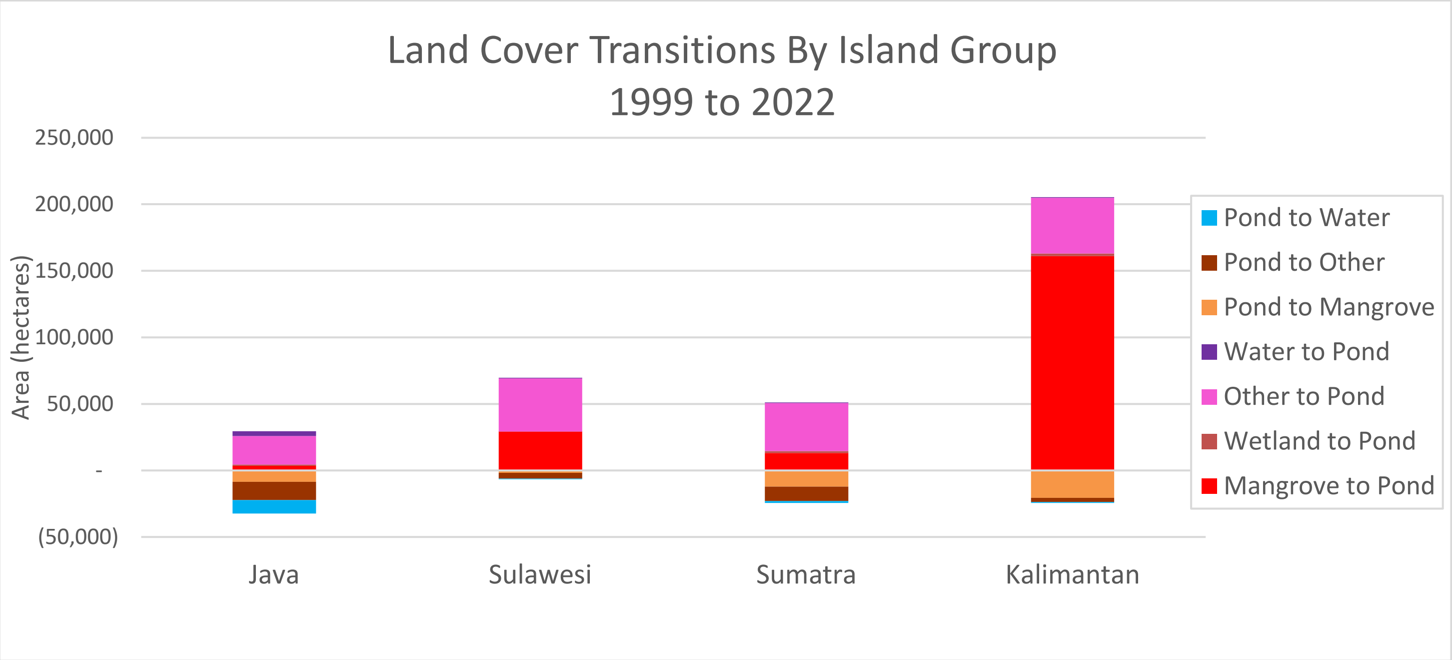

Figure 4: Land cover transitions in Indonesia from 1999 to 2020. The color scheme is intended to be similar to that of the Clark Labs data. Brackish-water pond area in Indonesia from 1989 to 2020. 1989 value from Sari (2015) and 1999 to 2020 from Clark Labs.

Table 9: Provinces with substantial mangrove and wetland conversion to ponds between 1999 and 2022. Source Clark Labs.

Island	Province	Deforestation Areas (Mangrove & Wetland to Pond) from 1999 to 2022 (Hectares)
Kalimantan	Kalimantan Utara	86,051
Kalimantan	Kalimantan Timur	57,759
Kalimantan	Kalimantan Selatan	13,768
Sulawesi	Sulawesi Selatan	6,410
Sulawesi	Sulawesi Tenggara	8,070
Sulawesi	Gorontalo	5,068
Sumatra	Sumatera Selatan	9,965
Sumatra	Aceh	3,454
Sumatra	Sumatera Utara	2,825
Java	Jawa Barat	2,568
Java	Jawa Tengah	1,304
Java	Jawa Timur	575

(57%) in Kalimantan. That is, more than half the ponds present in Kalimantan in 2022 had been built in high-value habitats after 1999. There is one reference stating that some of the more recent conversion on Sulawesi is from protected mangrove areas and is illegal (Basorie, W. D., 2022), but further details were not readily available. Besides this one reference, there is no readily available information contextualizing the mangrove development as illegal in other locations/islands, despite the various mangrove laws, protections, and farm siting regulations (see Factor 3.2). Note that pond to mangrove land-use conversion is discussed in Factor 3.2a.

Table 10: Pond area dynamics for the major island groups between 1999 and 2020, and between 2018 and 2020. Data for pond area and land use change from Clark Labs; production by species from MAFF, 2019.

	Kalimantan	**Java**	**Sulawesi**	**Sumatra**	**Lesser Sunda Islands**
Total pond area in 2022 (ha)	287,244	194,032	190,251	152,992	9,245
Area of mangrove + wetland conversion to ponds 1999–2022 (ha)	163,062	4,490	29,229	14,640	1,077
Percentage of 2022 ponds converted from mangroves and wetlands after 1999	57%	2%	15%	10%	10%
Area of mangrove + wetland to ponds 2020–22 (ha)	5,787	399	554	1,140	5
Production of *L. vannamei* in 2022 (MT)	1,166	257,159	116,743	148,699	186,042
Production of *P. monodon* in 2022 (MT)	34,392	40,630	21,273	32,081	126

The most recent data available from Clark Labs (2020 to 2022) indicate that the conversion of mangroves and wetlands to ponds is ongoing to some degree in each of the main island groups, particularly in Kalimantan (≈2,000 ha per year from 2020 to 2022), but to a lesser extent in the other island groups (Java: 133 ha per year; Sulawesi: 185 ha per year; and Sumatra: 330 ha per year). But there is a trend of reduced conversion rates. The 2020 to 2022 data signal that conversion is slowing down dramatically compared to the 1999 to 2022 totals—an encouraging change from the overall trend during this period, which appears to be mainly driven by growth from 1999 to 2014 (see Figure 2). Figure 5 shows the average annual area of mangroves and wetlands converted to ponds in each island group for the two periods (1999 to 2022 and 2020 to 2022). It can be seen that the average annual area converted in Kalimantan between 2020 and 2022 is much lower (72% lower) than that between 1999 and 2022, indicating a reduction in the annual rate of conversion. The annual rate has also declined sharply in Sulawesi (≈85% lower), and although relatively low overall, has decreased in Java (≈29%) and in Sumatra (≈38%).

As a result, it appears that two-thirds of the total brackish-water pond area across Indonesia was developed before 2000, and the total pond area has largely stabilized since 2014. There is some marginal conversion of mangroves since 1999 on each of the major brackish-water pond area islands except Kalimantan, where there has been substantial mangrove conversion since 1999.

Scoring Analysis

Overall, the available data show a complex pattern of habitat conversions across the islands, species, and timeframes. Robust data to differentiate this conversion by pond production system are not readily available across Indonesia, and while there are likely to be some clear differences (such as the use of extensive ponds for *P. monodon* in Kalimantan), no attempt is made to differentiate production systems in the analysis here.

But by considering the habitat conversion characteristics of each island group and the dominant species produced, some distinctions by species can be made. For example, the majority of the 2022 pond area in Kalimantan (57%) composes ponds that have been built in high-value habitats after 1999, and with an

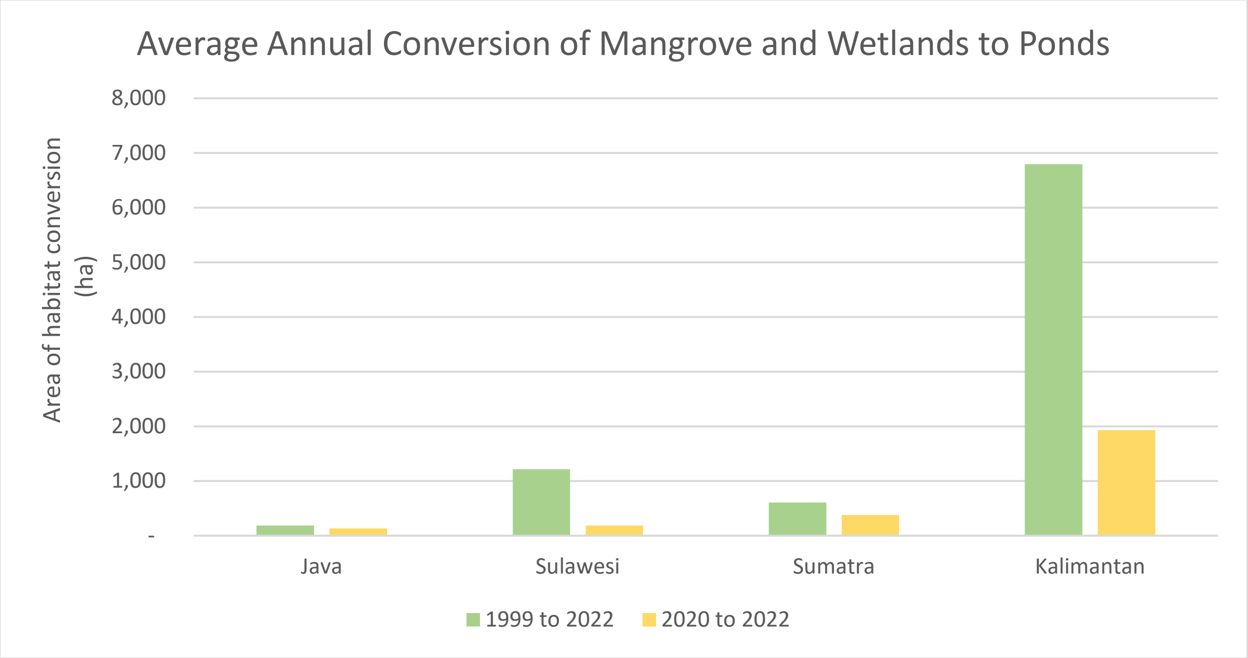

Figure 5: Average annual area of mangrove to pond conversion by island group between 1999 and 2020 and between 2018 and 2020. Data from Clark Labs.

annual average conversion of ≈2,000 ha between 2020 and 2022, this is considered to be ongoing, although the recent (2020 to 2022) reduction in the annual conversion rate is encouraging. Thus, the typical or average farm in Kalimantan is considered to have been built in high-value habitats after 1999, and with ongoing conversion, the score for Factor 3.1 for Kalimantan is 0 out of 10. According to the species-island harvest figures (see Table 2 in the Introduction), 27% of Indonesian *P. monodon* are produced on Kalimantan (with very little *L. vannamei*).

For the other islands, the data from Clark Labs indicate that the majority of the total pond area was not built in high-value habitats after 1999 (Java: 98%; Sulawesi: 85%; Sumatra: 90%; and the Lesser Sunda Islands 90%). Therefore, the typical or average shrimp farm on these islands is considered, on a precautionary basis, to have been built in high-value habitats before 1999,[76] and the score for these islands is 4 out of 10 (note that the smaller scale, ongoing conversion of high-value habitats is addressed in Factor 3.2 as a weakness in the current regulatory system). The island harvest figures indicate that *L. vannamei* is the dominant species on these islands. Table 13 provides a summary.

Differentiating the scores for Factor 3.1 by species is of greater relevance than by island, because the shrimp supply chain is typically differentiated at the species/country level rather than by island (e.g., shrimp are typically sold as whiteleg shrimp from Indonesia or giant tiger prawn from Indonesia).[77] Table 13 shows that, by considering the different species production characteristics across the main island groups, a weighted score for Factor 3.1 for each species can be determined that more closely reflects the associated habitat conversions across Indonesia.

---

[76] That is, although some farms will have been built in low-value habitats such as former rice paddies (which themselves may have been converted from mangroves), given the historic development of the shrimp farming industry in Indonesia, the majority is considered, on a precautionary basis, to have been built in mangroves.

[77] As opposed to being differentiated by the island on which it was produced.

Table 11: Values used in the determination of a weighted species score for Factor 3.1 based on the proportions of each species produced on each island.

	Kalimantan	Java	Sulawesi	Sumatra	Lesser Sunda Islands	Total
Percentage of 2022 pond area converted from mangroves and wetlands after 1999	57%	2%	15%	10%	10%	n/a
Island score for Factor 3.1	0	4	4	4	4	n/a
Island percentage of *P. monodon* production	27%	32%	17%	25%	0%	100%
Island percentage of *L. vannamei* production	0.0%	36%	17%	21%	26%	100%
Weighted island/species score for Factor 3.1 for *P. monodon* (0–10)	0.0	1.28	0.68	1	0	**2.96**
Weighted island/species score for Factor 3.1 for *L. vannamei* (0–10)	0.0	1.44	0.68	0.84	1.04	**4.00**

The weighted island/species scores in Table 13 show that, across Indonesia as a whole, the Factor 3.1 scores for *P. monodon* and *L. vannamei* are 3 out of 10 and 4 out of 10, respectively. This broadly agrees with Bulcock et al. (2022), who suggested that *P. monodon* farming within intertidal areas is driving the observed mangrove losses in Indonesia, but also cautioned that this is far from conclusive.

Conclusion: Factor 3.1

The conversion of mangroves or wetlands to aquaculture ponds is considered to result in a loss of the important ecosystem services typically associated with those habitat types. Nearly 1 million hectares, or 22%, of Indonesia's total mangrove forest area were deforested from 1800 to 2012, with a clear correlation with initial shrimp farming islands (Java, Sumatra, Sulawesi, and Kalimantan). If evaluating just these major shrimp producing islands, nearly half of the historical total mangroves have been lost (≈49% or ≈ 1.3 million hectares from 1800 to 2022). By island, there is a historical mangrove reduction from 1800 to 2022 of 73% on Java, 54% on Sulawesi, 39% on Kalimantan, and 30% on Sumatra. Noting that correlation is not causation, and that there is not a robust consensus as to how much of a driver shrimp farming was to mangrove land-use change, the general literature does consider shrimp farming to be a substantial driver historically. As a result, it appears that the mangrove forests of these islands have been majorly affected, at least in part, by the conversion of mangroves to shrimp farms. By comparing the total shrimp pond area in 1999 and 2022, it appears that roughly two-thirds of the pond area present in 2022 was developed before 1999 (with some exceptions as noted): an important baseline for this assessment. The most recent data available indicate that there is still ongoing conversion of mangroves within each of the significant shrimp farming areas—Kalimantan, Java, Sulawesi, and Sumatra—although the rate of conversion between 2020 and 2022 has declined for all regions. Altogether, there is a complex pattern of habitat conversion across the islands, species farmed, and timeframes, but by considering the habitat conversion characteristics of each island group and the dominant species produced, some distinctions can be made:

- The typical or average farm in Kalimantan is considered to have been built in high-value habitats after 1999, and there is recent or ongoing conversion. The score for Factor 3.1 for Kalimantan is 0 out of 10. According to the species-island harvest figures (from 2022; Table 2), nearly one-third of Indonesia's *P. monodon* is produced on Kalimantan, with minor *L. vannamei* production.
- For the other islands, the majority of the total pond area was not considered to have been built in high-value habitats after 1999 (Java: 98%; Sulawesi: 85%; Sumatra: 90%; and the Lesser Sunda Islands: 90%). Thus, the typical or average shrimp farm on these islands is considered, on a precautionary basis, to have been built in high-value habitats before 1999, and the score for these islands is 4 out of 10. The island harvest figures indicate that both species are produced to varying degrees on these islands, but *L. vannamei* is dominant.

By considering the different species' production characteristics across the main island groups (Table 2), a weighted score for Factor 3.1 for each species can be determined that more closely reflects the associated habitat conversions across Indonesia. As a result, the weighted species scores across Indonesia for Factor 3.1 are 3 out of 10 for *P. monodon* and 4 out of 10 for *L. vannamei*.

Factor 3.2—Farm siting regulation and management

Factor 3.2a—Content of habitat management measures

The national and regional agencies responsible for managing shrimp farm siting and habitat protections are numerous in Indonesia. The general permitting process and legislation governing shrimp pond aquaculture in Indonesia is explained at length in Effluent Factor 2.2a. Elaborated upon here are the habitat management protections and framework. Note that, while the discussion on habitat conversion in Factor 3.1 considered an extended period (primarily pre- and post-1999), the following discussion relates to the current regulations and management measures regarding new or expanding shrimp farms in Indonesia, and therefore relates primarily to recent and ongoing habitat conversion.

Site Selection (Zonal Approach)

It is the role of each province and its respective regional planning agency (BAPPEDA) to develop a detailed development plan, with resource use zones determined by an ecosystem's carrying capacity. When implemented, these policies are intended to help create a theoretical framework for area-based aquaculture zones. According to MMAF, farms are required to be within an aquaculture zone (pers comm, MMAF, 2021). But there has been a failure to develop consistent spatial management guidance/legislation integrated with other industries at the regional level across Indonesia (see Factor 2.2a) to meet the ideals of the national legislation. This may be a symptom of the decentralized approach to government in Indonesia. A Zoning Plan for Coastal Areas and Small Islands (RZWP3K) for each province was made available through personal communication (pers comm, Anonymous, 2021) for this assessment (it appears that the plans were once available on the MMAF website, but are no longer; pers comm, Bulcock, 2024). These zoning and spatial development plans for each province outline the policies, regulations, and spatial statistics of different categorical zonal uses, along with development goals, to integrate industries in the coastal and small island regions. This includes brackish-water shrimp aquaculture, mangrove forest protected areas, and restoration zones. While it is apparent that there are aquaculture zones, there is no supporting evidence (e.g., results, methods, study citations) that the ecological carrying capacity of these areas have been defined—an important component of Presidential Decree No. 21—2021 Implementation of Spatial Planning and the business licensing process (discussion follows). Also, without an ecological carrying capacity study or reference, the additional conversion of mangroves and wetlands since 1999 (especially within Kalimantan, Sulawesi, Sumatra and Java; see Table 13) are quite concerning. For example, the conversion within Kalimantan may be occurring within an aquaculture zone, but without guidance of a carrying capacity study, the conversion appears to be continuing the degradation of the mangrove ecosystems.

In addition to the broad environmental protections discussed in Factor 2.2a, Presidential Decree No. 32-1990 provides guidance for farm siting. In this decree, appropriate mangrove green belts are defined as the width of mangrove forests necessary for coastal protection, based on the tidal range and distance from rivers/waterways. The 1990 decree was developed to succeed attempts to protect mangroves and institute green belts in the 1970s (Ilman et al., 2016). It appears that the defined width of a green belt was further modified in 2016 (Presidential Decree No. 51) and is now dependent on the distance from the coast and other waterways; i.e., within 50 m along waterways and 100 m inland from the highest tide along the coast (Bosma et al. 2020).

But evidence of the effectiveness of this regulation must be questioned, considering the mangrove deforestation described in Factor 3.1, satellite imagery demonstrating noncompliance, and deforestation that occurred soon after its passing (see Factor 3.2b) (Ilman et al., 2016) (Boyd et al., 2021b) (Clark Labs). As discussed in Criterion 2—Effluent, Factor 2.1a, there was a significant revision of relevant regulations in 2019, and a description follows of the current system.

Permitting

Currently, new and existing farms are able to utilize an online portal to upload and check license and permit documentation. The Online Single Submission (OSS) portal[78] helps to simplify the licensing procedures and is managed by the Ministry of Investment/Indonesian Investment Coordinating Board (pers comm, Pratiwi, 2021). To obtain a business license (SIUP), the regional department for site recommendations and the governing licensing department must receive and process a business permit application. Part of the application consists of determining if the proposed shrimp cultivation area is compliant with the regional spatial management plan (*SNI 8228-1:2022;* BSN, 2022), whether the area is free from flooding, and if the location is compliant with the mandatory green belt described previously.[79] [80]

Once the initial business license is approved, environmental licensing (or permitting) is the main regulatory control for environmental protections, which is evaluated through a spectrum of risk. This is generally formulated for shrimp aquaculture based on size; that is, larger farms (measured in hectares) are associated with a greater risk and require a greater review for environmental compliance. The different environmental reviews (AMDAL, UKL-UPL, and SPPL) are summarized as follows.[81]

<u>Environmental Impact Analysis (EIA) or AMDAL</u>

An Environmental Impact Analysis (Analisa Mengenai Dampak Lingkungan or AMDAL) is required if a business will have significant impacts to the environment. For shrimp farms, this is applicable for farms

---

[78] oss.go.id

[79] SMART Fish Indonesia, 2023, citing Presidential Regulation Number 51 of 2016 concerning coastal boundaries; Law No. 26 of 2007 concerning spatial planning; and Law No. 27 of 2007 concerning management of coastal areas and small island; MMAF, 2021.

[80] Due to multiple regulations and in turn definitions of greenbelts, greenbelts are used in this assessment as at least 100 m inland and 50 m from the river.

[81] List of mandatory environmental impact analysis businesses. Ministerial Regulation Environment and Forestry No.4 (2021).

≥500 ha or those located within or directly adjacent to a protected forest[82] (more on protected forests follows). Relevant components of an EIA for habitat include a review of the carrying capacity, environmental impact and risk assessment, ecosystem services, resilience and potential of biodiversity, vulnerability, and adaptive capacity to climate change.[83] All applications are examined by agency employees, certified experts (detailed in attachment 4), the governor of the province, and the regent/mayor (Government Regulation of the Republic of Indonesia Number 22, 2021). If the application and EIA are approved, a proposed Environmental Management Plan must be vetted as well. The Environmental Management Plan's purpose is to identify environmental impacts, categorize them from minimal to significant, and determine monitoring/mitigation efforts. Monitoring plans include the data type, sampling location, frequency, and method, along with mitigation plans. The type of activities that require monitoring and mitigation plans are not directly evident in the literature, but any perceived impacts must not exceed the carrying capacity of the environment.

Program of Environmental Management and Monitoring (UKL-UPL)

Shrimp farms between 10 ha and 500 ha size are not considered to have a significant impact (in isolation), and only require statements of environment management efforts (Upaya Pengelolaan Lingkungan, UKL) and environment monitoring efforts (Usaha Pengelolaan Lingkungan-UPL). The UKL-UPL form identifies impact sources and magnitude, along with the corresponding mitigation measure and monitoring, which defers to the relevant environmental management standard (assumed to be the corresponding IndoGAP CBIB standard, and the various Standard Operating Procedures from GQSP UNIDO[84]). The resulting activities relating to the impact, monitoring, and mitigation required are then identified.[85] The type of activities that require monitoring and mitigation plans are not directly evident in the literature, but any perceived impacts must not exceed the carrying capacity of the environment. The final approval is given by the lead provincial environmental office.

Small farms: Statement of Environmental Management and Monitoring Capability (SPPL)

Shrimp farms < 10 ha must only provide a statement of commitment to abide by environmental protections and to manage and monitor the environment (Surat pernyataan pengelolaan lingkungan, SPPL).

Evaluation

The zonal approach to site selection and the pre-review of environmental impacts and corresponding mitigation plans outlined previously appear, on paper, to be effective, area-based, and cumulative management frameworks based on ecological principles and environmental considerations. But the significant historical conversion of mangrove ecosystems that continues to varying degrees across Indonesia indicates that the legislation to realize the habitat protections is undermined by the regulatory guidance for a more favorable development approach. As a result, the carrying capacities of some regions/ecosystems have been exceeded.[86] Important elements required to realize the intent of the legislation (e.g., an understanding of carrying capacity, habitat connectivity) seem to be absent from

---

[82] According to ELAW, 2020 there are six laws that create a framework and definition for mangrove protected areas. For brevity, it is referenced here, but see the website and ensuing laws for details: https://www.elaw.org/indonesia-select-mangrove-laws

[83] Implementation of environmental management and protection. Appendix I. No. 22 (2021)

[84] SMART Fish Indonesia, 2021 and 2023

[85] Implementation of environmental management and protection. Appendix III. No. 22 (2021)

[86] Technical guidelines for the management of aquaculture areas with an ecosystem approach. No. 154/Per-DJPB (2019).

the readily available literature; therefore, the gaps between the legislation and the implementing regulations create a management framework that cannot be considered cumulative.

For example, the concessions of coastal areas for pond aquaculture development and the following individual farm siting review are mandated to operate within the carrying capacity of the environment, as dictated in the spatial management scheme. But documentation/studies of the carrying capacity, its limits, and current status could not be found, and the clear ongoing conversion of mangrove habitat demonstrates the gap between policy and practice. Also, the ongoing development of new land and the abandonment of old ponds may create an accounting balance for land area, but the regulations do not appear to ensure habitat connectivity (crucial for biodiversity and ecosystem functionality), which is an ongoing issue in Indonesia. This creates a spatial management scheme that lacks a cumulative management framework.

Thus, ecological considerations and principles are considered within the national legislation, but in practice, the regulatory framework and guidance for farm siting do not appear to meet these national legislative ideals.

Mangrove forest protected areas and restoration

There are mangrove-specific protected areas and rehabilitation efforts in Indonesia; for example, the National Strategy for Mangrove Ecosystem Management (Nurhati and Murdiyarso, 2023)[87] and The State of Indonesia's Forests (2022)[88] by MOEF provide a good overview of current mangrove ecosystem management activities, monitoring, reporting, and verification of mangrove conditions and opportunities for improvement.

Since 2012, there have been numerous restoration efforts for mangroves, along with government projects and working groups (see Sasmito et al. 2023 for a summary), with varying levels of success. For example, a goal of restoring 600,000 hectares by 2024 was created, and is monitored by the Indonesia Peatland and Mangrove Restoration Agency (BRGM) (Basorie, 2022) (Nurhati and Murdiyarso, 2023). Despite this goal, a recent study estimates that only 30% of the target area is suitable for restoration, while shortcomings for current restoration rates (only 50% of the target between 2017 and 2020 was reached, or 5,138 ha) are reportedly due to unclear planning and/or inappropriate strategies (Sasmito et al., 2023), thus demonstrating the importance of adaptive management.

Across Indonesia, there are six protected mangrove areas, which combine to protect 1,826,207.05 ha, or about 22% of the total mangrove coverage in the country (Arifanti, V.B., 2020). The protection type (legal framework) is not clear, because the farm siting process creates loopholes or opportunities to site within protected areas (see the previous section on AMDAL). There are many international, national, and local efforts to improve mangrove protected areas and expand their coverage for various motivations, and these efforts appear dynamic (Miteva, D.A, 2021) (Pusparini et al. 2023) (Sasmito et al. 2023). Given the importance of mangrove ecosystem services, their protection and rehabilitation are important areas to monitor, especially as climate change persists and carbon storage and carbon markets gain greater traction globally.

The Clark Labs coastal land-use change data are used here as a proxy to suggest possible evidence of areas where mangrove restoration have occurred, although it is noted that there are challenges to using

---

[87] https://www.cifor-icraf.org/publications/pdf_files/WPapers/CIFOR-ICRAF-WP-14.pdf

[88] https://backpanel.kemlu.go.id/Shared%20Documents/The%20State%20of%20Indonesias%20Forest%202022.pdf

these data to justify effective reforestation. For example, the pond-to-mangrove land-use change transition may suggest reforestation efforts, but the quality of this land-use transition or its attributes (such as whether it is natural recolonization, a change to silvoculture, or active reforestation/interventions) are unclear. Nevertheless, the land-use change data are a potentially useful indicator of large spatial-scale trends over time. Using this land-use change layer, there are ten provinces with a total of over 1,000 hectares of pond to mangrove transition from 1999 to 2022 (Table 14). Cross-referencing the provinces listed in Table 14 with Table 11 (i.e., provinces with substantial mangrove and wetland conversion to ponds between 1999 and 2022), every province listed as a major area of reforestation is also an area of major deforestation (except Lampung). But as shown in Table 10, the only island that has a net positive (i.e., gain) in mangrove coverage since 1999 is Java. This further illustrates the challenges of land-use transitions and mangrove accounting, and emphasizes the need for further research and reforestation over time to help restore these important ecosystems and their benefits.

Table 12: Provinces with substantial ponds to mangrove land use change from 1999 to 2022. Source: Clark Labs.

Island	Province	Reforestation Areas (Pond to Mangrove) from 1999 to 2022
Kalimantan	Kalimantan Timur	9,533
Kalimantan	Kalimantan Utara	9,461
Java	Jawa Timur	5,095
Sumatra	Aceh	4,766
Sumatra	Sumatera Selatan	3,313
Sumatra	Sumatera Utara	2,689
Java	Jawa Barat	2,181
Kalimantan	Kalimantan Selatan	1,362
Sumatra	Lampung	1,089
Java	Jawa Tengah	1,051

Conclusion—Factor 3.2a

Habitat management measures that define the ongoing development of shrimp farming in Indonesia are based on ecological principles, yet appear limited in specific regulations or guidance that would demonstrably achieve those principles. It is up to each province—and the respective regional planning agency (BAPPEDA)—to develop a detailed development plan with resource use zones determined by an ecosystem's carrying capacity (as reflected in the RZWP3K—Zoning Plan for Coastal Areas and Small Islands). Despite the frequent acknowledgement of the importance of carrying capacity studies, there is no readily available information demonstrating that an effective carrying capacity study has been defined or implemented (i.e., supportive regulation/guidance). Thus, important management principles such as cumulative impacts and habitat connectivity do not appear to be addressed effectively. In addition, farm siting within aquaculture zones requires an application for a permit and/or license; however, the associated requirements for environmental review and their rigor are dependent on the size of the planned farm, and it is unclear what habitat protections are mandated. For farms ≥ 500 ha, an environmental impact assessment (EIA) is required, and approval is given if the EIA included a determination of the impact the farm may have to the carrying capacity of the aquaculture zone, which itself may or may not have been defined. Farms of ≤ 500 ha but ≥ 10 ha must provide an application and receive approval for a statement of environmental management efforts and environment monitoring efforts for farms (UKL-UPL), though the only applicable habitat protection is a requirement to be sited within an aquaculture zone. This is also applicable for farms < 10 ha, which require a statement of commitment to abide by environmental protections (SPPL). One of the clear environmental protections of the permitting process is the requirement to site farms outside of the greenbelt, yet there appear to be shrimp farms sited and developed within the green belt since the passing of Presidential Decree No. 32 in 1990. Despite the inconsistencies in environmental protections, there have been and continue to be substantial conservation efforts to protect and/or restore mangroves in Indonesia, but these have often been hampered by poor planning and/or execution. Overall, the habitat management framework in Indonesia appears to lack the content necessary to demonstrably achieve its own ecological principles for sustainable aquaculture (i.e., based on carrying capacity and cumulative management). As a result, the content of habitat management measures is limited, and Factor 3.2a scores 2 out of 5.

Factor 3.2b—Enforcement of habitat management measures

As noted, the agencies responsible for managing shrimp farm siting and habitat protections are numerous in Indonesia and include a combination of national and regional agencies. The Directorate General of Aquaculture within the Ministry of Marine Affairs and Fisheries (MMAF) is the primary authority for enforcing regulations regarding shrimp farm operations in Indonesia, and oversees technical implementation units (i.e., the Directorate of Surveillance and Control of Marine and Fishery Resources (PSDKP)). The Ministry of Environment and Forestry (MoEF) is also a leading authority on enforcing environmental compliance. Other offices and agencies involved include the National Investment Coordinating Board and local government: governors, regents, spatial planning offices, the inspector from the secretariate office, and the Police of the Republic of Indonesia (pers comm, Faturakhmat, FUI and MMAF, 2021) (FishSource citing Hatfield, 2018). Further insight as to the location, number of employees, and other statistics regarding the capacity of MMAF and local agencies tasked with enforcing environmental compliance to the shrimp farming industry is limited.

The main mechanism for evaluating and enforcing shrimp farm compliance to environmental standards, such as farm siting, is through permitting, audits and inspections, and imposing sanctions (i.e., penalties) (Utomo et al., 2021). At an area level, farms must be compliant and located within the designated aquaculture zones, which define the carrying capacity of ecosystems and whether more farms may be assimilated. Farms must also be compliant with Presidential Decree No. 32-1990 and Presidential Decree No. 51-2016, where farms cannot be sited within mangrove greenbelts (Ilman et al., 2016) (Bosma et al., 2020). Yet, as discussed in Factor 3.2a, the framework to enforce appears convoluted, and it is ultimately left to the local agencies and provinces to develop the scientific basis for carrying capacities, the justifying aquaculture zones, and the permit siting assurance. It does not appear that farm siting is consistently enforced to the regulatory framework, because examples of farms developed since 1999 that are not compliant with the greenbelt legislation can be seen in satellite imagery (Figure 6).

Nevertheless, examples of active enforcement of mangrove regulations can also be found in many reports investigating illegal mangrove clearance.[89]

As stated, the initial application helps define the type of environmental license that is applicable, which is determined based on the perceived risk of the shrimp aquaculture farm, which in turn is interpreted based upon the size of the farm. The resulting environmental license requires either an EIA, UKL-UPL, or SPPL. Each permitted license describes the environmental monitoring that must be carried out by the business owner in compliance with the relevant environmental license (Protection and Management of the Environment. No. 32, 2009). For habitat, this appears to include only reviewing the location and ensuring that farms are operating legally (i.e., have all necessary licenses and permits), which occurs during the field inspections. There are no additional requirements for IndoGAP certification for habitat protections. The frequency of field inspections varies, depending on the assigned risk and compliance history, and may be multiple times per year, but evidence of enforcement is unclear. The results of inspections and all permits are stored on the online single submission (OSS) government portal (see Factor 2.2b for details of enforcement and penalties). There are a range of potential penalties for noncompliance of environmental approval (including imprisonment) but, depending on the type and severity, may lead to warnings, suspensions, or revocation of business license. The government portal was not readily accessible, so data describing evidence of compliance or noncompliance rates were not readily available.

---

[89] Lampung regional police arrest suspect destroying mangroves on the coast of Bandar Lampung City (July 3, 2023) https://diskursusnetwork.com/2023/07/03/polda-lampung-tangkap-perusak-mangrove-di-pesisir-bandar-lampung/ and may be a follow-up to shrimp pond development (June 11, 2023) https://diskursusnetwork-com.translate.goog/2023/06/11/hutan-mangrove-dijadikan-tambak-udang-polda-lampung-kembali-periksa-saksi/?_x_tr_sl=auto&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=wapp A man was arrested for clearing ≈7 ha total of mangroves near the Bukit Mangkol Grand Forest Park Forest Aria in the Central Bangka Regency, Bangka Belitung Islands Province in March of 2023. Public reports of the clearing were brought to the Director of Criminal Law Enforcement at the Ministry of Environment and Forestry who investigated and later arrested the man who faces up to 10 years in prison and a maximum fine of IDR 5 billion https://www-wowbabel-com.translate.goog/nasional/5988250434/penyidik-gakkum-klhk-tangkap-perusak-kawasan-hutan-mangkol-pelaku-terancam-10-tahun-penjara-dan-denda-rp-5-m?_x_tr_sl=auto&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=wapp Case of mangrove destruction on the coast in the Sandana Village Tolitoli Regency, Central Sulawesi Province. https://ppid.menlhk.go.id/berita/siaran-pers/6920/berkas-perkara-lengkap-kasus-perusakan-mangrove-yang-melibatkan-kepala-desa-segera-disidangkan#:~≈:text=Sarkodes%20terancam%20hukuman%20pidana%20penjara,.1%2F12%2F2022 Fugitive Mangrove Destroyer in East Belitung Arrested. https://infopublik.id/kategori/nasional-sosial-budaya/852782/buronan-perusak-mangrove-di-belitung-timur-ditangkap

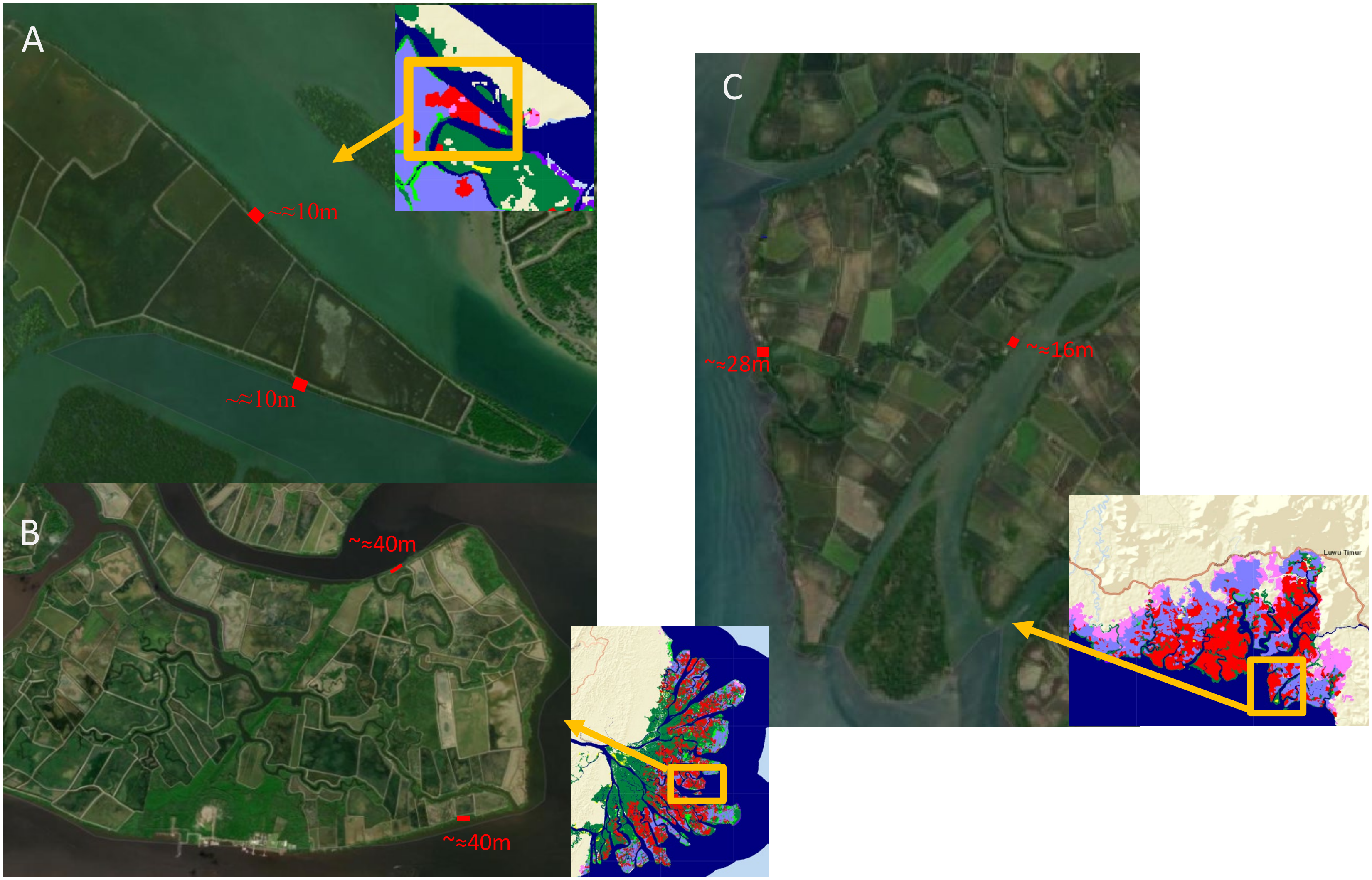

Figure 6: Satellite images show pond development since 1999 within greenbelt demonstrating non-compliance with Presidential Decree no. 32 of 1990 or Presidential Regulation no. 51 of 2016. Each image cluster (denoted by a letter – —A, B or C) shows Clark Labs satellite image layer of pond conversion since 1999 illustrated in red – —this is the smaller image – —the larger satellite image is the zoomed in scope as defined in the yellow outline box. This larger satellite image shows the distance from coastal waters to the pond embankment; the greenbelt width. The locations of photos by province are starting in the top left (A) Aceh, (B) Kalimantan Timur, and Sulawesi Selatan. Measures are approximate and were measured in Environmental Systems Research Institute ArcGIS software.

Outside of the created aquaculture zones, there are six designated protected mangrove ecosystems across Indonesia. The level of protection is unclear, and the effectiveness of the enforcement of these protections is questionable. As mentioned in Factor 3.1, the Advocacy Network for Natural Resources Management (JAPESDA) director Nurain Lapolo states, “90% of the mangroves in the Tanjung Panjang Nature Reserve [in Gorontalo province on the island of Sulawesi] have been illegally cleared to make way for shrimp and fish ponds” (Basorie, W. D., 2022). There are national laws, regulations, and agencies overseeing the management of mangrove ecosystems; however, for decades, mangrove deforestation has continued. A review of Indonesian national policies for mangrove management from 1932 to 2017 by Arifanti, V.B. (2020) discusses the ongoing friction between development and conservation of this important natural resource. From this analysis, the continued deforestation is due to a combination of weak enforcement and conflicting policies (Arifanti, V.B., 2017 citing Ilman, et al., 2011; Friess et al., 2016; Simarmata, R., 2020). In addition, the differing scopes of management agencies create apparent challenges. As of 2020, Arifanti (2020) notes that there are five institutions that are responsible for mangrove management in Indonesia: the Coordinating Ministry of Maritime and Investment, Ministry of Environment and Forestry, Ministry of Fisheries and Marine Affairs, Ministry of National Development Planning (Bappenas), and Coordinating Ministry for Economic Affairs. This has led to inconsistencies in management, zoning, and enforcement of mangrove protections.

As stated, there have been numerous restoration efforts for mangroves, and in order to meet the goals set by the Indonesian government for mangrove protections and restoration, the associated regulations and enforcement must be adjusted and given priorities. Arifanti (2020) notes the following recommendations for mangrove restoration:

> “(1) enhance coordination between sectors and stakeholders; (2) solve conflicting land tenure issues; (3) adhere to the appropriate mangrove growth ecological prerequisites; (4) prepare careful rehabilitation planning; (5) increase mangrove conservation areas; (6) put a halt on mangrove conversion to other land-uses; (7) allocate long term monitoring program; and (8) involve local communities in mangrove rehabilitation and management.”

Conclusion—Factor 3.2b

Numerous national and provincial agencies can be identified that are charged with managing shrimp farm siting and mangrove protections. The location of farms (e.g., regarding designated aquaculture zones or mangrove greenbelts) is enforced through permit applications and field audit visits. While evidence of enforcement activities can be found, information on the overall compliance rates is not readily available, and there is some evidence to suggest that enforcement of the regulations is minimal. There is one report of illegal clearance and encroachment of mangrove forests, but this may be an isolated occurrence. There is a clear pattern, as detailed in Factor 3.1, of ongoing land-use change of mangroves to brackish-water ponds on every island where there is significant pond area, which appears to contradict national legislation. The ongoing conversion may be due to the differing scopes of management agencies and national goals creating apparent challenges for the government to enforce mangrove protections and farm siting effectively and consistently across Indonesia. Restoration remains an ongoing priority, with some success but also with evidence of poor planning and execution. Altogether, it appears that enforcement activities are difficult to identify, with little evidence of monitoring or compliance data and limited evidence of penalties for infringements. As a result, the Factor 3.2b score is 1 out of 5.

Therefore, the overall effectiveness of the management system (for all production systems) is considered to be limited, and the score for Factor 3.2—Farm siting regulation and management (which combines Factors 3.2a and 3.2b) is 0.8 out of 10.

Conclusions and Final Score

The conversion of mangroves or wetlands to aquaculture ponds is considered to result in a loss of the important ecosystem services typically associated with those habitat types. Nearly 1 million hectares, or 22%, of Indonesia's total mangrove forest area were deforested from 1800 to 2012, and for major shrimp producing islands, nearly half of their historical total mangroves have been lost (≈49% or ≈1.3 million hectares from 1800 to 2022, or 73% loss on Java, 54% on Sulawesi, 39% on Kalimantan, and 30% on Sumatra). Noting that there is some uncertainty in the scale of shrimp farming's role in this long-term mangrove land-use change, the general literature does indicate that the mangrove forests of these islands have been majorly affected by their conversion to shrimp farms. By comparing the total shrimp pond area in 1999 and 2022, it appears that roughly two-thirds of the pond area present in 2022 was developed before 1999 (with some exceptions, as noted): an important baseline for this assessment. The most recent data available (2020–22) indicate that there is still ongoing conversion of mangroves within each of the significant shrimp farming areas—Kalimantan, Java, Sulawesi, and Sumatra—although the most recent data show that the rate of conversion between 2020 and 2022 has declined for all regions. Altogether, there is a complex pattern of habitat conversion across the islands, species farmed, and timeframes, but by considering the characteristics of each island group and the dominant species produced, some distinctions can be made:

- The typical or average shrimp farm in Kalimantan is considered to have been built in high-value habitats such as mangroves or wetlands relatively recently (after 1999), and there is evidence of recent or ongoing conversion. The score for Factor 3.1 for Kalimantan is 0 out of 10. Harvest data indicate that nearly one-third of Indonesia's *P. monodon* is produced on Kalimantan, with no significant *L. vannamei* production.
- For the other islands, the typical or average shrimp farm is also considered, on a precautionary basis, to have been built in high-value habitats, but mostly before 1999 (Java: 98%; Sulawesi: 85%; Sumatra: 90%; and the Lesser Sunda Islands: 90%). The score for these islands is 4 out of 10. The island harvest figures indicate that both species are produced to varying degrees on these islands, but *L. vannamei* is dominant.

By considering the different species' production characteristics across the main island groups, a weighted score for Factor 3.1 for each species can be determined that more closely reflects the associated habitat conversions across Indonesia. As a result, the weighted island/species scores across Indonesia for Factor 3.1 are 3 out of 10 for *P. monodon* and 4 out of 10 for *L. vannamei*.

Current habitat management measures that define the recent and ongoing development of shrimp farming in Indonesia are based on ecological principles, yet appear to be limited in their implementation. It is up to each province—and the respective regional planning agency (BAPPEDA)—to develop a detailed development plan, with resource use zones determined by an ecosystem's carrying capacity as reflected in the RZWP3K—Zoning Plan for Coastal Areas and Small Islands. But although aquaculture zones have been defined, there is no readily available information demonstrating that an effective carrying capacity study has been defined or implemented (i.e., supportive regulation/guidance). Without a transparent and justified spatial management plan, important management principles such as cumulative impacts and habitat connectivity do not appear to be incorporated. Farm siting within aquaculture zones requires a permit and/or license, for which the associated environmental review and its rigor is dependent on the size of the planned farm, but it is unclear what habitat protections are mandated through this process (if any) for any size of farm. Presidential Decrees No. 32 of 1990 and No. 51 of 2016 state aquaculture farms cannot be sited within a green belt (100 m from the coast and 50 m from inland waterways) to act as a buffer for mangrove forests, but evidence suggests that these are not effectively enforced in the farm siting process. There have been substantial conservation efforts to protect and replant mangroves in Indonesia, which have had some success but have fallen short of lofty goals and expectations. Overall, the content of the habitat management framework is considered to lack a clear demonstration of the practical measures necessary to effectively achieve the ecological principles underpinning sustainable aquaculture, carrying capacity, and cumulative management. As a result, the content of habitat management measures is limited and Factor 3.2a scores 2 out of 5.

There are numerous national and provincial agencies charged with managing shrimp farm siting and mangrove protections, but there is a clear pattern (as detailed in Factor 3.1) of ongoing land-use change of mangroves to brackish-water ponds on every island where there is significant pond area. The siting of shrimp farms in aquaculture zones and outside mangrove greenbelts is enforced through permit applications and field audit visits, but compliance rates are unknown, and there is some evidence to suggest that enforcement of these regulations is minimal (one report of illegal clearance and encroachment of mangrove forests was found, but it is not known if this is an isolated occurrence). The ongoing conversion may be due to the differing scopes of management agencies and national goals, which create challenges for the government to enforce mangrove protections and farm siting effectively and consistently across Indonesia. Restoration remains an ongoing priority, with some success. Altogether, it appears that enforcement organization and their activities are difficult to identify, with little evidence of monitoring or compliance data and limited evidence of penalties for infringements. As a result, the Factor 3.2b score is 1 out of 5. Therefore, the overall effectiveness of the management system (for all production systems) is considered to be limited, and the score for Factor 3.2 (combining Factors 3.2a and 3.2b) is 0.8 out of 10.

Combining Factors 3.1 and 3.2 results in the following scores for Criterion 3—Habitat:

- *L. vannamei* intensive is 2.93 out of 10
- *L. vannamei* semi-intensive is 2.93 out of 10
- *L. vannamei* extensive is 2.93 out of 10
- *P. monodon* extensive is 2.27 out of 10.

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: limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms.

Criterion 4 Summary—All Production Systems

Chemical Use parameters	Score	Critical?
Intensive systems: C4 Chemical Use Score (0–10)	3	No
Semi-intensive systems: C4 Chemical Use Score (0–10)	3	No
Extensive systems: C4 Chemical Use Score (0–10)	6	No

Brief Summary

There is limited published and verifiable information available from the government, industry, or literature detailing the current chemical use (or lack thereof) of shrimp farms in Indonesia. What is known about pond preparation chemicals (such as lime), disinfectants, and piscicides indicates that their use is a relatively low concern. In contrast, the lack of detailed, publicly available information regarding the types and quantities of antimicrobial usage limits the potential analysis of this criterion, and (along with global concerns regarding the overuse of antimicrobials) drives a precautionary approach for this group of chemicals. Thus, antimicrobials are the focus of this assessment.

Under the Ministerial Regulation on Fish Medicine (No.1-2019), Indonesia permits six antimicrobials for aquaculture, of which four are classified as highly important for human medicine by the World Health Organisation (WHO) and two are classified as critically important. Although some restrictions on the use of these antimicrobials are in place (for example, requirements for a veterinary prescription), there do not appear to be any regulatory limits on the frequency of use or on their total use. The lack of publicly available information documenting antimicrobial usage (e.g., total use, frequency, type, distribution, and sales) also obscures any objective measures to understand enforcement effectiveness. In addition, academic literature, though limited, indicates limited enforcement of broader antimicrobial policies across several industries in Indonesia (including aquaculture). There are many studies that highlight the potential risk of antimicrobial usage in the environment, and numerous studies detect antimicrobial residues and bacterial resistance to (sometimes multiple) antimicrobials in shrimp or shrimp ponds in Indonesia. These include antimicrobials classified as highly important and critically important to human medicine by WHO, and one prohibited in Indonesia (chloramphenicol). Yet there is no readily available information that clearly implicates antimicrobial usage on shrimp farms in these findings. In contrast, there are indications that some sectors of the shrimp farming industry use no antimicrobials (especially for *P. monodon*), but the lack of robust data again confounds solid conclusions in this regard.

Overall, the lack of information means that the chemical use characteristics of shrimp farms in Indonesia are effectively unknown. Some regulatory limits are in place that primarily restrict the types of treatments permitted, but the enforcement effectiveness is unclear. Other governance mechanisms, such as extension guidance for antibiotic-free disease management (more in Criterion 7—Disease) and processors refusing shrimp that test positive for antibiotic residues, appear to be fairly effective, and there have been no import refusals for antibiotic residues since 2018. Nonetheless, antibiotics are still detected in and around shrimp farms, and shrimp farms and their products are associated with various aspects of antimicrobial resistance, including resistance associated with antimicrobials that are important for human health. Therefore, while there are some management measures with demonstrated effective enforcement limiting the use of chemicals (a score of 4 out of 10), there is also evidence in the literature of chemical use on shrimp farms that discharge into the environment, and data concerning the use of chemicals are unavailable (a score of 2 out of 10). The available information generates a precautionary high level of concern, and *L. vannamei* grown in semi-intensive and intensive production systems score an intermediate 3 out of 10 for Criterion 4—Chemical Use. Although data are also limited for *P. monodon* and *L. vannamei* extensive farms, they have low stocking densities with large pond areas and little input, and according to government regulators, *P. monodon* does not use any chemical inputs. Therefore, although it is not assumed that these farms are entirely chemical free, they are considered to have a low need for chemical use, and the final score for extensive *P. monodon* and *L. vannamei* is 6 out of 10 for Criterion 4—Chemical Use.

Justification of Rating

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

Detailed information regarding the chemical use on shrimp farms in Indonesia is limited. As will be discussed, some understanding of current usage could be obtained from academic literature and personal communications, yet more granular information regarding the type, total quantity, and application frequency of chemicals was scarce. The chemicals used include pond preparation agents (such as lime, disinfectants, piscicides, probiotics) and veterinary medications (such as antimicrobials and pesticides). The focus of this criterion is on antimicrobials and pesticides along with the regulations and legislation governing their use, because these are typically associated with the greatest environmental (and/or human health) concerns.

Regulations/Legislation for all Chemical Use

Regulations, legislation, and standards like IndoGAP govern the use, distribution, and manufacturing of chemicals and medicines for aquaculture in Indonesia. The supply and circulation (i.e., distribution) of fish medicine are controlled through Ministerial Regulation No.1-2019 Fish Medicine. Fish medicine is defined as a “preparation that can be used to treat fish, relieve symptoms, or modify chemical processes in the fish body” while “fish” includes all aquatic organisms. The regulation outlines which chemicals are permitted or prohibited (details will follow), in addition to aspects relating to the production process, circulation, and quality control of ingredients.

All aquaculture chemicals sold in Indonesia must have a Fish Drug Registration Certificate, with a label detailing the composition, method of use, designation/indication target fish, and withdrawal time, if an antibiotic (Ministerial Regulation No.1-2019 Fish Medicine). The regulation defines the following types of drug class:

- Hard drug
    - "when used not in accordance with the provisions can cause danger to fish, the environment, and/or humans [who] consume fish, and its use must be with a veterinarian's prescription."
    - May be prohibited or allowed.
- Limited over-the-counter drugs
    - "… are strong drugs for fish that are treated as an over-the-counter drug[;] for fish species[,] certain conditions [are] provided with the amount, dosage rules, dosage forms, and how to use and given a special warning sign."
- Over-the-counter
    - "… is fish medicine that can be obtained and used freely."

The types of chemical compounds of fish medicine are defined as premix, pharmaceutical, biological, probiotic, and herbs/natural medicines. According to Dahuri (2020), the number of registered fish medicines totals 353—see Table 15 for total by group. All chemical producers must report every 6 months the "number and types of fish medicines that have been produced and circulated, for the manufacture of fish medicines in Indonesia" (Ministerial Regulation No.1-2019 Fish Medicine). If imported, reporting is every 3 months to the Director General: "the amount and type of fish medicine entered and circulated." Failure to comply results in a warning given within 1 month, then revocation of certificate (Ministerial Regulation No.1-2019).

Table 13: Number of registered fish medicines by group. Source: Dahuri, R., 2020.

Group	Total
Premix	186
Pharmaceutical	59
Biological	34
Probiotic	67
Herbs/Natural Medicines	7

The types of permitted or prohibited chemicals are listed in Tables 16 and 17. It is important to note that this list of permitted chemicals includes antimicrobials listed as highly and critically important to human medicine by the World Health Organization (WHO, 2019). Also, it is unclear how the active substances allowed for use listed in Table 16 relate to the grouping of fish medicines in Table 15.

Antimicrobials

In general, as aquaculture production intensifies, there is a greater risk of disease incidences, which may increase the usage of antimicrobials, and thus the risk of antimicrobial resistance (Schar et al., 2020). One of the most concerning issues with the use of antimicrobials (also commonly referred to as antibiotics) is that it may pose a risk to human health (Gräslund and Bengtsson, 2001) because

Table 14: Types of chemicals allowed for use. Source: Ministerial Regulation No.1-2019 Fish Medicine.

Category	Legality	Type	Group	Active Substance
Hard Drug	Legal	Antimicrobial	Tetracycline	Chlortetracycline*
Hard Drug	Legal	Antimicrobial	Tetracycline	Oxytetracycline*
Hard Drug	Legal	Antimicrobial	Tetracycline	Tetracycline*
Hard Drug	Legal	Antimicrobial	Macrolides	Erythromycin**
Hard Drug	Legal	Antimicrobial	Fluoroquinolones	Enrofloxacin**
Hard Drug	Legal	Antimicrobial	Sulfonamides	Sulfadiazine*
Hard Drug	Legal	Nonantimicrobial	Anthelmintic	Emamectin
Hard Drug	Legal	Nonantimicrobial	Dyes	Methylene blue
Hard Drug	Legal	Nonantimicrobial	Dyes	Basic Bright Green Oxalate
Hard Drug	Legal	Nonantimicrobial	Dyes	Acriflavine
Hard Drug	Legal	Nonantimicrobial	Dyes	Brilliant Blue
Hard Drug	Legal	Nonantimicrobial	Dyes	Tartrazine
Hard Drug	Legal	Nonantimicrobial	Dyes	Alura Red
Hard Drug	Legal	Nonantimicrobial	Dyes	Ponceau-4R
Hard Drug	Legal	Nonantimicrobial	Dyes	Sunset Yellow
Hard Drug	Legal	Nonantimicrobial	Hormones	Gonadotropin Releasing Hormone (GnRH)
Hard Drug	Legal	Nonantimicrobial	Hormones	Luteinizing Hormone Releasing Hormone analogue (LHRHa)
Hard Drug	Legal	Nonantimicrobial	Hormones	Human Chorionic Gonadotropins (HCG)
Over-the-Counter	Legal	Disinfectant and Antiseptic		Merthiolate (Thiomersal)
Over-the-Counter	Legal	Disinfectant and Antiseptic		Benzalkonium Chloride
Over-the-Counter	Legal	Disinfectant and Antiseptic		Boric Acid
Over-the-Counter	Legal	Disinfectant and Antiseptic		Chlorine
Over-the-Counter	Legal	Disinfectant and Antiseptic		Chloramine
Over-the-Counter	Legal	Disinfectant and Antiseptic		Copper Sulfate
Over-the-Counter	Legal	Disinfectant and Antiseptic		Formaldehyde (formalin)
Over-the-Counter	Legal	Disinfectant and Antiseptic		Iodine
Over-the-Counter	Legal	Disinfectant and Antiseptic		Povidone Iodine
Over-the-Counter	Legal	Disinfectant and Antiseptic		Phenoxethol
Over-the-Counter	Legal	Disinfectant and Antiseptic		Potassium Permanganate (PK, $KMnO_4$)
Over-the-Counter	Legal	Disinfectant and Antiseptic		Peroxide Compound
Over-the-Counter	Legal	Disinfectant and Antiseptic		Cresol
Over-the-Counter	Legal	Disinfectant and Antiseptic		Thymol
Over-the-Counter	Legal	Disinfectant and Antiseptic		Glutaraldehyde
Over-the-Counter	Legal	Disinfectant and Antiseptic		Sodium Thiosulfate
Over-the-Counter	Legal	Disinfectant and Antiseptic		Saponins
Over-the-Counter	Legal	Miscellaneous		Vitamin
Over-the-Counter	Legal	Miscellaneous		Mineral
Over-the-Counter	Legal	Miscellaneous		Amino acid

* Antimicrobial listed as highly important for human medicine by the World Health Organization.

** Antimicrobial listed as critically important for human medicine by the World Health Organization.

Table 15: Types of chemicals not allowed for use. Source: Ministerial Regulation No.1-2019 Fish Medicine.

Category	Legality	Type	Group	Active Substance
Hard Drug	Illegal	Antimicrobial	Amphenicol	Thiamphenicol
Hard Drug	Illegal	Antimicrobial	Amphenicol	Chloramphenicol
Hard Drug	Illegal	Antimicrobial	Amphenicol	Fluorphenicol
Hard Drug	Illegal	Antimicrobial	Nitroimidazole	Dimetridazole
Hard Drug	Illegal	Antimicrobial	Nitroimidazole	Metronidazole
Hard Drug	Illegal	Antimicrobial	Nitroimidazole	Fluconazole
Hard Drug	Illegal	Antimicrobial	Nitroimidazole	Tinidazole
Hard Drug	Illegal	Antimicrobial	Nitrofuran	Nitrofurantoin
Hard Drug	Illegal	Antimicrobial	Nitrofuran	Nifurpirinol
Hard Drug	Illegal	Antimicrobial	Nitrofuran	Furazolidone
Hard Drug	Illegal	Antimicrobial	Nitrofuran	Nifurtoinol
Hard Drug	Illegal	Antimicrobial	Nitrofuran	Furaltadon
Hard Drug	Illegal	Antimicrobial	Macrolides	Virginiamisina
Hard Drug	Illegal	Antimicrobial	Macrolides	Tilosina
Hard Drug	Illegal	Antimicrobial	Macrolides	Spiramycin
Hard Drug	Illegal	Antimicrobial	Polypeptide	Zinc Basitrasina
Hard Drug	Illegal	Antimicrobial	Miscellaneous	Ronidazole
Hard Drug	Illegal	Antimicrobial	Miscellaneous	Dapsone
Hard Drug	Illegal	Antimicrobial	Miscellaneous	Chlorpromazine
Hard Drug	Illegal	Antimicrobial	Miscellaneous	Cholichicin
Hard Drug	Illegal	Nonantimicrobial	Dyes	Malachite Green
Hard Drug	Illegal	Nonantimicrobial	Dyes	Leuco Malachite Green
Hard Drug	Illegal	Nonantimicrobial	Dyes	Crystal Violet (gentian violet)
Hard Drug	Illegal	Nonantimicrobial	Dyes	Leucocrystal Violet
Hard Drug	Illegal	Nonantimicrobial	Hormones	Synthetic Estradiol (diethyl stilbestrol, benestrol, dienestrol)
Hard Drug	Illegal	Nonantimicrobial	Hormones	17y-Methyltestosterone
Hard Drug	Illegal	Nonantimicrobial	Hormones	HGPs (Growth Promoter Hormones)
Hard Drug	Illegal	Nonantimicrobial	Anesthetics and sedatives MS-22	Tricaine methanesulfonate
Hard Drug	Illegal	Nonantimicrobial	Organophosphates	Ether
Hard Drug	Illegal	Nonantimicrobial	Organophosphates	Trifluralin
Hard Drug	Illegal	Nonantimicrobial	Organophosphates	Dichlorvos
Hard Drug	Illegal	Nonantimicrobial	Organophosphates	Trichlorfon
Hard Drug	Illegal	Nonantimicrobial	Plants	*Aristolochia* spp.

significant or improper use of these drugs can further the development of antimicrobial-resistant pathogens, including those capable of cross-species and zoonotic transmission (Holmström et al., 2003). Note the term “antimicrobial” is the preferred term here, but “antibiotic” (within which antimicrobials are a category) is also used when referencing the work or statements of others.

Country-Level Use

Ministerial Regulation No.1-2019 Fish Medicine requires reporting on antimicrobial manufacture, circulation, or import; unfortunately, the data generated do not appear to be readily available. Therefore, to get a sense of the possible total antimicrobial use across Indonesian aquaculture, the findings of Schar et al. (2020) are discussed.

Global aquaculture usage of antimicrobials in 2017 was estimated by Schar et al. (2020) to be 10,259 tons (95% uncertainty interval of 3,163 to 44,727 tons). Of this total, Indonesia was estimated to use 8.6% or 882.27 tons in 2017 (after China with 57.9% and India with 11.3%), which is significant. It is also important to note that only 2.7% of this global aquaculture antimicrobial usage in 2017 was attributed to shrimp production (Schar et al., 2020). Although the use of antimicrobials is affected by many complex factors, these authors (Schar et al.) note that a trend of increasing use is expected to continue, following the intensification and usage feedback loop described previously. It should be noted that the confidence in the accuracy of the antimicrobial estimates by Schar et al. (2020) are admittedly low (see the limitations section of the paper). But in the absence of better data, the findings of Schar et al. (2020) demonstrate that there is concern about the total use of antimicrobials in the Indonesia aquaculture industry.

Governance of Antimicrobial Use

Noting the permitted and prohibited chemicals in Tables 16 and 17, regulations and legislation controlling the use of antimicrobials in Indonesia are limited, particularly for limiting the frequency of use and/or the total quantity used. According to Siahaan et al. (2022), there are reportedly high levels of environmental antimicrobial resistance due to multisectoral misuse, which includes industries such as healthcare, livestock, and aquaculture. There appears to be limited coordination between these sectors, and “the government has to take stronger measures to oversee better implementation of AMR [antimicrobial resistance] policies.” (Siahaan et al. 2022). Also, the focus of Ministerial Regulation No.1-2019 Fish Medicine regarding antimicrobial usage is to control what is available (i.e., permitted), ease of use (e.g., requirements for a veterinary prescription[90]), and sufficient withdrawal time so that any residues are compliant with international import laws (i.e., United States and the European Union). Despite these control policies, Siahaan et al. (2022) note that livestock farmers easily obtain antimicrobials and circumvent the requirement for a veterinary prescription. Also, there do not appear to be any regulations or legislation that limit the frequency or total quantity of antimicrobial use over a specified period or at a specific farm. There is guidance, though, from a Standard Operating Procedure document compiled by UNIDO (GQSP, 2023) stating that antimicrobials must only be used for targeted treatment and not for prevention (i.e., prophylaxis).

Additional laws governing antimicrobial usage are focused on food safety. These include (as summarized by Wahidin et al. 2018), Law No. 45/2009 Fishery Law, Government Regulation No. 57/2015 Quality and Food Safety law of Fishery Products, and a similar regulation by MMAF, Regulation No. PER.19/MEN/2010 and Ministerial Decree No. 02 of 2007 on Good Aquaculture Practices.

Enforcement of the legislation regarding antimicrobial usage is the responsibility of the Deputy General of Aquaculture and its Directorate of Fish Health and Environment and Sub Directorate Residue. Inspection (i.e., monitoring and evaluation) of export products (e.g., shrimp) is conducted by quarantine centers every 6 months, while inspections for antimicrobial residues occur on shrimp farms every year

---

[90] See Ministerial Regulation No.1-2019 Fish Medicine discussion in the previous section.

(Siahaan et al. 2022). Across Indonesia, there are residue monitoring labs in 19 provinces,[91] which test for a number of substances (i.e., legal and illegal antimicrobials) from shrimp samples, including chloramphenicol, nitrofurans, nitroimidazole, tetracyclines, quinolones, sulfonamides, anthelmintics, heavy metals, and dyes (malachite green and crystal violet) (Dahuri, R., 2020). If there is usage of legal antimicrobials, farmers are directed to harvest only after the withdrawal time (Regulation No. 75-2016 General guidelines for rearing *monodon* and *vannamei* shrimps). Although unconfirmed in the literature, it is common practice for shrimp to be sampled for any antimicrobial residue upon harvest by either farmers, brokers, or processing centers, for food safety concerns and to minimize rejections from large export markets of Indonesian shrimp such as the United States and the European Union (pers comm Susanto, Farthing, Faturakhmat, Widigo, Wibowo, 2023). Nevertheless, Siahaan et al. (2022) still detailed the need for improved antimicrobial policies (as stated previously), including improved enforcement, but there is some evidence of improving outcomes; for example, Wahidin et al. (2018) noted that EU rejections of shrimp for chloramphenicol detection (originally banned in 1988) have been zero since additional food safety laws were passed (e.g., Law No. 45/2009).

Compliance with the IndoGAP standard for shrimp farming involves following fish medicine usage requirements (i.e., there are no shrimp-specific requirements). This includes keeping records of any drug use including antimicrobials, while antimicrobials must be “used under the supervision of a veterinarian/fish health expert (prescription, testing, withdrawal time).” In addition, all fish medicines in possession must be registered, and their use must comply with the drug labels. It is important to note that the IndoGAP standard does not explicitly limit the amount of antimicrobials used (i.e., the frequency or total quantity) but does require that any fish medicine used does not negatively affect the environment (BSN, 2022).

Some farms voluntarily have policies and/or practices in which no antimicrobial use is allowed. For example, although evidence was not readily available, personal communication with FUI states that any antibiotic use on shrimp farms will not be accepted at the processing units. Thus, this agreement between farms and the processors elevates antimicrobial governance beyond the regulatory requirements of the Indonesian government.

On-Farm Usage of Antimicrobials

Data describing on-farm usage of antimicrobials in the shrimp farming industry in Indonesia are quite limited and fragmented, so it is challenging to determine a clear pattern of use (or lack thereof). The perceived driver of any use is likely the high disease prevalence across the industry (see Criterion 7—Disease). The only direct evidence of antimicrobial usage on farms readily available from literature is highly circumstantial, with no real evidence presented. For example, Indah (2022) states that antibiotics (e.g., chloramphenicol, nitrofuran, dimetridazole) are added to fish feed. Wulan et al. (2020) mention reliance on antibiotics for *P. monodon*, but no further context or understanding of production systems. Sarjito and Sabdono (2021) state that antibiotics are used by Indonesian shrimp farmers to combat vibriosis outbreaks, but the statement was not cited. And according to Saputra et al. (2020), “Chloramphenyl [chloramphenicol] is still widely used in animals, especially tiger shrimp.”

---

[91] Aceh, North Sumatera, South Sumatera, Lampung, Banten, West Java, Central Java, DI Yogyakarta, East Java, Bali, West Nuse Tenggara, West Kalimantan, East Kalimantan, North Kalimantan, South Kalimantan, South East Sulawesi, Central Sulawesi, West Sulawesi, and South Sulawesi.

In contrast, there are several sources suggesting that there is limited or no use of antimicrobials in shrimp farming; for example, based on the findings of an ASEAN Guidelines document (2013),[92] no antibiotics are used in Indonesian aquaculture, though no data were available for oxytetracycline. Andriyono et al. (2022) sampled *L. vannamei* shrimp from intensive ponds in Banywangi and found that they were free of any antibiotic (e.g., tetracycline, oxytetracycline, and chloramphenicol) residue. According to contacts from the Indonesian Fishery Producers Processing and Marketing Association (AP5I), AP5I only accepts shrimp that have not been treated with antibiotics, since about 2006 (pers comm, AP5I, 2021), and AP5I members account for roughly 90% of Indonesia's shrimp exports (pers comm, AP5I, 2024). Also based on the statements of Central Proteina Prima (CPP), there is no usage of antibiotics in *L. vannamei* farms in the Lampung area (pers comm, CPP, 2021). MMAF states that there is no use of antibiotics or chemicals in general in extensive *P. monodon* farms, which is consistent with other Seafood Watch assessments of extensive production.[93]

Other stakeholder interviews for this assessment also state that there is no antibiotic usage on Indonesian shrimp farms (pers comm, Farthing, Faturakhmat, Widigo, Wibowo, 2023) (pers comm, PT, Central Proteina Prima, Utari, 2025). This is due to a few forces that discourage any usage (pers comm, Dr. Bambang Widigo and Mr. Budi Wibowo, 2023) (pers comm, Alexander Farthing 2023):

a) social pressure—the Indonesian Shrimp Forum (SCI) met 10–15 years ago to declare that there will be no more antibiotic use, in response to pressure from the European Union;
b) most of the pathogens are viral, so antibiotics would not be helpful;
c) main force—the processor will check shrimp for antibiotics, and if found, farmers will be blacklisted; residue sampling will typically occur at the pond harvest or at the processing center. If the processor sells a container with antibiotics, there will be financial and reputational penalties.

While this information is useful, it is hard to consider because there is no documentation or evidence to help support these claims. There is a need to develop primary data (e.g., data, grey literature, and academic literature) to help document and support these important claims.

In contrast to the findings of Andriyono et al. (2022) and the ASEAN (2013) guidance document previously noted, additional academic literature, while limited, features several studies that provide alternative or indirect insights into antimicrobial usage on farms (using various techniques including environmental monitoring for the presence of antibiotics on or near shrimp farms in Indonesia, bacteria resistant to antimicrobials, and tests for the presence of antimicrobial residues in shrimp). For example, Hidayati et al (2021) tested for several antimicrobials using water samples taken from four locations in Central Java. In each location, samples were taken from shrimp farms at the inlet, pond, and outlet, as well as control locations along the coast. At all farm locations, the antimicrobial "Oxytetracycline was the most abundant…"—indicating its possible use in aquaculture activities, although the detection varied from 0% to a maximum of 11.5% of samples in aquaculture areas (oxytetracycline is one of the most frequently used antibiotics in aquaculture systems) (Hidayati, L. et al. 2021). The highest level was found at the outlet canals because they carry the unfiltered discharge; there is no treatment into the canal system of multiple shrimp ponds (Hidayati, L. et al. 2021).

---

[92] Guidelines for the use of chemicals in aquaculture and measures to eliminate the use of harmful chemicals (2013) https://repository.seafdec.org.ph/handle/10862/5880

[93] See the Seafood Watch aquaculture assessment of Vietnam shrimp https://www.seafoodwatch.org/globalassets/sfw-data-blocks/reports/s/seafood-watch-whiteleg-shrimp-giant-tiger-prawn-vietnam-27793.pdf

Regarding bacterial resistance to antimicrobials, Mulya et al. (2022) tested bacteria (e.g., *Vibrio parahaemolyticus*) taken from shrimp ponds (no further information) that showed multiple resistance against ampicillin (100% of samples) and tetracycline (42% of samples). No resistance was shown to chloramphenicol, ciprofloxacin, and enrofloxacin (Mulya et al., 2022). Sumini and Kusdarwati (2020) sampled bacteria, *Vibrio harveyi.*, from farmed *L. vannamei* infected with white feces disease (WFD) in East Java from November 2017 to September 2018. In total, there were 30 samples collected: 10 samples taken from 3 farm locations in East Java—2 were semi-intensive and 1 was an intensive pond. Results showed that 100% of the *V. harveyi* bacteria were resistant to oxytetracycline and erythromycin, and 80% of the samples were resistant to enrofloxacin, thus demonstrating the resistance to multiple antibiotics. Sarjito and Haditomo (2016) sampled bacteria (*V. vulnificus*, *V. parahaemolyticus*, *V. harveyi*, *V. mimicus*, and *V. fluvialis*) from intensive ponds in East Java and found that they were resistant to erythromycin, enrofloxacin, and oxytetracycline. Also, Kusmarwati et al. (2017) sampled *V. parahaemolyticus* bacteria from *L. vannamei* taken directly from shrimp ponds in West, Central, and East Java and found the bacteria resistant to multiple antibiotics (e.g., streptomycin, erythromycin, amoxicillin/clavulanic acid, and nitrofurantoin).

Recently, Virgianti et al. 2022 found chloramphenicol residues from shrimp sampled from grow-out ponds in Banyuwangi. The author also cites other papers where chloramphenicol residues are also detected from farmed shrimp and/or grow-out ponds (Juliana and Yulian, 2020; Putra, 2021; Sasmita, 2020). Similarly, Siahaan et al. (2022) reviewed policies and reports and conducted interviews with key stakeholder groups on the status and challenges of antimicrobial governance in Indonesia. According to the interview with a district fisheries office in South Sulawesi, chloramphenicol was the most significant residue in their annual reports (assumed here to mean the most frequently detected).

For all the sources listed previously from academic literature, the antibiotics detected (by water samples, bacterial resistance, and residue) were oxytetracycline, ampicillin, tetracycline, erythromycin, enrofloxacin, and chloramphenicol. All of these are permitted for use in Indonesia, but only through a veterinary prescription—except chloramphenicol, which was banned in 1988 (as noted). According to the World Health Organisation, oxytetracycline, chloramphenicol, and tetracycline are highly important antimicrobials for human medicine, while ampicillin, enrofloxacin, and erythromycin are critically important antimicrobials for human medicine (WHO, 2019).

Despite the findings of these studies, they do not provide direct evidence of antimicrobial use on shrimp farms. As summarized by Wahidin et al. (2018), antimicrobial detection in shrimp or shrimp ponds (e.g., residue, bacterial resistance, and water samples) may be caused by factors beyond the farms. For example, poultry farming, other livestock systems, healthcare, sewage, and perhaps even usage at shrimp hatcheries may be sources of antimicrobial detection (Neela et al., 2015) (Hidayati, L. et al., 2021) (Kusmawarti et al., 2017) (Wahidin et al. 2018). As a result, the conflicting circumstantial evidence described here means that no robust conclusions can be made about the scale (amount and frequency) or types of antimicrobials used (if any) in Indonesian shrimp farms.

U.S. Import Rejections

Shrimp that are imported into the United States must comply with domestic U.S. Food and Drug Administration regulations to ensure seafood that is "safe, sanitary, wholesome and honestly labeled." This includes testing shrimp for antibiotic residues. Refusal of imports, for various charges, are documented and available for access on the U.S. FDA dashboard.[95] Results, pulled from the U.S. FDA

---

[95] https://datadashboard.fda.gov/ora/cd/imprefusals.htm

database, show eight import rejections of Indonesian shrimp from 2014 to June 2022, and no rejections after 2018:

- Residue samples testing positive for nitrofuran (once each in 2014, 2015, and 2018)
- Residue samples testing positive for "VetDrugRes" (three times in 2015, twice in 2018).

Again, the rejections of these shrimp imports do not implicate on-farm antimicrobial usage, because the contamination can come from a number of sources, but it is important to note that there are no import rejections for the past 5 years for antimicrobial residues. A similar pattern is observed in the European Commission RASFF database, where only one import alert is recorded, in 2023 for the pesticide triphenyltin.[96] It is also important to note that a lack of rejections or alerts does not imply a lack of legal antimicrobial use, because the effective use of withdrawal periods reduces the antimicrobial residues to levels below the rejection thresholds.

The low refusal rate of imported Indonesian shrimp in the United States is in stark contrast to other major shrimp producing and exporting countries (i.e., India, Vietnam, Malaysia, China, and Bangladesh).[97] Therefore, it would appear that the food safety and quality assurance enforcement framework in Indonesia is effective. All shrimp farmed in Indonesia must follow the *National Standard for Fresh Shrimp*, which requires physical and lab testing for chemical and bacterial residue at HACCP-certified processing facilities (Table 18) (pers comm, Purnama and Widigdo, 2024). As an additional layer of screening before export, the Fish Quarantine and Inspection Agency (BKIPM) samples and tests for chemical and biological residue for food safety standards (pers comm, Purnama and Widigdo, 2024). The emphasis on food safety and quality assurance for shrimp products has proved effective because there have been no import rejections for the past 5 years due to antibiotic residues; however, further data on farm practices and control of access to antibiotics would help to further characterize the enforcement effectiveness overall.

Table 16: Food quality and safety requirements. Source: pers comm, Purnama and Widigdo, 2024

Parameter	Unit	Condition
E. coli	Colony/g	Maximum 5.0×10^5
Salmonella	APM/25 g	Maximum < 2
Vibrio cholerae	APM/25 g	Negative
Chloramphenicol	µg/kg	Maximum 0
Nitrofuran	µg/kg	Maximum 0
Tetracycline	µg/kg	Maximum 100

Antimicrobial Use Summary

Overall, the control of antimicrobial usage through regulations and/or legislation, which would limit the access and potential use of antimicrobials, is not well understood. There are components of the regulatory or legislative structure that likely limit antimicrobial use, such as barriers to access through a veterinary prescription and only registered products are permitted, but the design of these regulations seems to aim primarily at assuring that Indonesian shrimp are compliant to export market requirements. For example, the banning of chloramphenicol in 1988 and the improved food safety regulations passed

---

[96] https://webgate.ec.europa.eu/rasff-window/screen/notification/635415

[97] https://shrimpalliance.com/southern-shrimp-alliance-releases-updated-databases-of-refused-shipments-of-antibiotic-contaminated-shrimp-imports-in-eu-japan-and-u-s-through-2021/

in 2009 resulted in total compliance and zero import rejections from the EU from 2009 to the present. This is an excellent example of effective regulations and enforcement of antimicrobial use. But the regulations are not designed to limit antimicrobial frequency or total use, and the barriers to access may not be strictly enforced. The lack of publicly available information documenting antimicrobial usage (e.g., total use, frequency, type, distribution, and sales) obscures any objective measures to understand enforcement effectiveness before processing, while academic literature, though limited, details ineffective enforcement across several industries. To add to the uncertainty, there are a number of studies that detect antimicrobial residue from shrimp, resistance of bacteria to multiple antimicrobials, and antimicrobial presence through water samples around farms. The antimicrobials detected are classified as highly important and critically important by the World Health Organisation (WHO) and, in the case of chloramphenicol, illegal in Indonesia. But there is no readily available information that clearly implicates antimicrobial usage on farms. Several sources of information suggest that there is no antimicrobial use on some shrimp farms at all (especially for *P. monodon*), but the applicability of these claims across Indonesian shrimp farms as a whole is not well understood, and the evidence is limited. The reduction in the import rejections is also encouraging. But considering all the factors, including the high disease prevalence (see Criterion 7—Disease), there are still significant information gaps and a lack of evidence to help define and clearly articulate farm practices and the effectiveness of regulations. Thus, the information that is available (and the general lack of readily available information) creates a precautionary high level of concern for the potential use of antimicrobials on shrimp farms in Indonesia. There is a clear need for more information on this subject, from academic research to industry claims.

Pond preparation, disinfectants, and piscicides

Other chemicals are used in the Indonesian shrimp farming industry, often for pond water and bottom preparation, but sometimes for disease management as well. These chemicals may include disinfectants, piscicides, and sediment amendments, and can be particularly hazardous to the environment and nontarget organisms (Rico et al., 2012). Indonesia has banned particularly hazardous chemicals, such as malachite green, crystal violet, and others, under Ministerial Regulation No.1-2019 Fish Medicine (see Table 17).

A common pond preparation/sediment amendment used in Indonesia is lime (in various forms, including calcium oxide, calcium carbonate, and dolomite lime), which is used to raise the pH of pond bottoms drying between crop cycles, to destroy disease-causing organisms (Boyd et al., 2018) (pers comm, CPP, MMAF, Faturakhmat, Pratiwi, 2021); the use of lime or similar amendments is not considered a risk to the environment.

A list of other chemicals commonly used was acquired through personal communications and from guidance documents (GQSP, 2021), and it includes saponin (a piscicide), crustacide (active compounds unknown), nuvet (a crusticide, active compound diazinon), potassium permanganate, chlorine, and copper sulphate. Their purposes are to disinfect water and soil in reservoirs or ponds that may contain disease-causing organisms, as well as serving as piscicides and crustacides to control predators or carriers of disease-causing organisms (Boyd et al., 2018) (Sivaramakrishnan, T., & Renganathan, R., 2013) (Yasir et al. 2021) (pers comm, CPP, GQSP UNIDO, Faturakhmat, Pratiwi, 2021). These compounds have high potential for acute toxicity, though most rapidly degrade in sediments and water (Rico and Van den Brink, 2014) (Rico et al., 2012), thus limiting the concern of impacts to the surrounding environment if discharged. In addition, these chemicals are generally applied as pond water treatment before post-larvae and are held within the grow-out ponds for a day or more (GQSP, 2021).

Conclusion and Final Score

There is limited published and verifiable information available from the government, industry, or literature detailing the current chemical use (or lack thereof) by shrimp farms in Indonesia. What is known about pond preparation chemicals (such as lime), disinfectants, and piscicides indicates that their use is a relatively low concern. In contrast, the lack of detailed, publicly available information regarding the types and quantities of antimicrobial usage limits the potential analysis of this criterion and (combined with global concerns regarding the overuse of antimicrobials) drives a precautionary approach for this group of chemicals. Thus, antimicrobials are the focus of this assessment.

Under the Ministerial Regulation on Fish Medicine (No.1-2019), Indonesia permits six antimicrobials for aquaculture, of which four are classified as highly important for human medicine by the World Health Organisation (WHO) and two are classified as critically important. Although some restrictions on the use of these antimicrobials are in place (for example, requirements for a veterinary prescription), there do not appear to be any regulatory limits on the frequency of use or on their total use. The lack of publicly available information documenting antimicrobial usage (e.g., total use, frequency, type, distribution, and sales) also obscures any objective measures to understand enforcement effectiveness. In addition, academic literature, though limited, indicates limited enforcement of broader antimicrobial policies across several industries in Indonesia (including aquaculture). There are many studies that highlight the potential risk of antimicrobial usage in the environment, and numerous studies detect antimicrobial residues and bacterial resistance to (sometimes multiple) antimicrobials in shrimp or shrimp ponds in Indonesia. These include antimicrobials classified as highly important and critically important to human medicine by WHO and one prohibited in Indonesia (chloramphenicol). Yet there is no readily available information that clearly implicates antimicrobial usage on shrimp farms in these findings. In contrast, there are indications that some sectors of the shrimp farming industry use no antimicrobials (especially for *P. monodon*), but the lack of robust data again confounds solid conclusions in this regard.

Overall, the lack of information means that the chemical use characteristics of shrimp farms in Indonesia are effectively unknown. Some regulatory limits are in place, primarily restricting the types of treatments permitted, but the enforcement effectiveness is unclear. Other governance mechanisms, such as extension guidance for antibiotic-free disease management (more in Criterion 7—Disease) and processors refusing shrimp that test positive for antibiotic residues, appear to be fairly effective, and there have been no import refusals for antibiotic residues since 2018. Nonetheless, antibiotics are still detected in and around shrimp farms, and shrimp farms and their products are associated with various aspects of antimicrobial resistance, including resistance associated with antimicrobials that are important for human health. Therefore, while there are some management measures with demonstrated effective enforcement limiting the use of chemicals (a score of 4 out of 10), there is also evidence in the literature of chemical use on shrimp farms that discharge into the environment, and data concerning the use of chemicals are unavailable (a score of 2 out of 10). The available information generates a precautionary high level of concern, and *L. vannamei* grown in semi-intensive and intensive production systems score an intermediate 3 out of 10 for Criterion 4—Chemical Use. Although data are also limited for *P. monodon* and *L. vannamei* extensive farms, they have low stocking densities with large pond areas and little input, and according to government regulators, *P. monodon* does not use any chemical inputs. Therefore, although it is not assumed that these farms are entirely chemical free, they are considered to have a low need for chemical use, and the final score for extensive *P. monodon* and *L. vannamei* is 6 out of 10 for Criterion 4—Chemical Use.

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: sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains.

Criterion 5 Summary

	L. vannamei intensive and semi-intensive		*P. monodon* and *L. vannamei* extensive	
Feed parameters	**Value**	**Score**	**Value**	**Score**
F5.1a Forage Fish Efficiency Ratio (FFER)	0.317		No Feed	
F5.1b Source fishery sustainability score		6		n/a
F5.1: Wild fish use score		7		10
F5.2a Protein INPUT (kg/100 kg fish harvested)	47.04		0.00	
F5.2b Protein OUTPUT (kg/100 kg fish harvested)	17.8		n/a	
F5.2: Net protein gain or loss (%)	62.16	3		10
F5.3: Species-specific kg CO_2-eq kg^{-1} farmed seafood protein	14.34	6		0.00
C5 Feed Final Score (0–10)		**5.95**		**10**
Critical?				

Brief Summary

There are some indications that feed may occasionally be used in extensive *P. monodon* and *L. vannamei* production, but overall, it is assumed to be insignificant for the purposes of this assessment. Therefore, the final score for Criterion 5—Feed for *P. monodon* and *L. vannamei* in extensive systems is 10 out of 10. For *L. vannamei* in fed semi-intensive and intensive systems, a variety of sources of feed information were used, including from farming companies, feed mills, certified farms, and academic literature. Nevertheless, information differentiating the specific feed characteristics of the two systems (e.g., eFCR, protein content, ingredients) was not robustly available. Therefore, the assessment was completed for *L. vannamei* independent of the production system, and the score applies to both semi-intensive and intensive production.

Using the available data, *L. vannamei* grown in intensive and semi-intensive production systems are calculated to have a forage fish efficiency ratio (FFER) of 0.31. This means that, from first principles, 0.31 MT of wild fish would need to be caught to produce 1.0 MT of farmed shrimp. Data describing marine ingredient sources were limited; however, some information, though missing key insights such as the fishing method and fishing location (e.g., FAO region), was made available to allow for a limited source fishery sustainability evaluation. The fishmeal and fish oil marine ingredients were derived from by-products (e.g., skipjack tuna, yellowfin tuna, and farmed Chilean Atlantic salmon) and whole fish (sardine and anchovies), resulting in a Factor 5.1b—source fishery sustainability score of 6 out of 10. The combined scores for Factor 5.1a (0.31) and Factor 5.1b (6 out of 10) result in a Factor 5.1—Wild Fish Use score of 7 out of 10 for *L. vannamei* in intensive and semi-intensive systems.

With an estimated average feed protein content of 33.6% for *L. vannamei* in intensive and semi-intensive systems, there is a substantial net protein loss of 62.2%, which results in a score for Factor 5.2—Net Protein Gain or Loss of 3 out of 10. The Feed Footprint (Factor 5.3) was estimated as 1,825.45 kg CO_2-eq per MT of shrimp feed and is driven by the substantial inclusion of soybean meal. Considering a whole harvest shrimp protein content of 17.8% for *L. vannamei* and an eFCR of 1.4, it is estimated that the feed-related global warming potential (GWP) of 1 kg semi-intensive and intensive farmed *L. vannamei* protein is 14.34 kg CO_2-eq. This results in a score of 6 out of 10 for Factor 5.3—Feed Footprint. Combined, the final score for Criterion 5—Feed for *L. vannamei* (in both semi-intensive and intensive production systems) is 5.95 out of 10. (See the Seafood Watch Aquaculture Standard for full details of the scoring calculations.)

Justification of Rating

The total feed used in Indonesia shrimp farms in 2021 was estimated to be 383,000 MT (Merican, 2021). Because there is minimal feed use for extensive production of *P. monodon* and *L. vannamei*,[98] nearly all of the demand for shrimp feed in Indonesia is for *L. vannamei* intensive and semi-intensive production. Thus, for the purposes of this assessment, it is assumed that feed use in extensive production is insignificant, and the score for Criterion 5—Feed is 10 out of 10 for *P. monodon* and *L. vannamei*.

Information differentiating semi-intensive and intensive feed characteristics (e.g., eFCR, protein content, ingredients) was not robustly available, so the following shrimp feed evaluation is for both semi-intensive and intensive *L. vannamei* production. The main shrimp feed manufacturing companies in Indonesia include CP Prima, CJ, Matahari Sakti, and Japfa STP ,which capture approximately 30%, 12%, 12%, and 12% of the market share, respectively (Van Der Pijl, W., 2023). There are roughly 11 other significant shrimp feed manufacturers in Indonesia (i.e., Cargill, Cheil Jedang, PT De Heus, Evergreen, Gold Coin, Grobest, Haid, Mabar Feeds, New Hope, Thai Union, and Tongwei) that capture the remaining ≈34% market share (Van Der Pijl, W., 2023). There are two fairly large feed mill associations: Indonesian National Independent Feed Association (APMN), with 40 members producing roughly 42,700 MT of animal feed, and the Indonesian Feedmills Association (GPMT), which comprises a variety of feed mill producers including 25 aquafeed companies (Minapoli, 2021). Anecdotally, it was reported that 80% of all semi-intensive and intensive shrimp farms in Indonesia source feed from seven Best Aquaculture Practices (BAP)-certified feed mills (pers comm, Sualia, 2024). Although the BAP standard includes sustainable sourcing requirements (e.g., sourcing of Marin Trust or Marine Stewardship Council fishmeal or fish oil), the standard's flexibility[99] and the lack of publicly available audit results make it challenging to confirm or assess the actual sources and sustainability of marine ingredients. Consequently, without

---

[98] See the Species Overview section for more details on how extensive production and farming practices were scoped.

[99] For example, if suitable MSC or Marin Trust certified sources of fishmeal or oil are unavailable in Indonesia, exceptions may be permitted.

detailed information from the feed mills, the BAP certification cannot be used as a definitive guide for ingredient sourcing in the following analyses.

Unfortunately, the specific ingredients and their inclusion levels in aquaculture feeds are seldom readily available because feed producers consider this information proprietary (Boyd et al., 2021a). Also, feed formulations may vary from batch to batch, depending on the price and availability of ingredients. So, developing a representative feed ingredient list, inclusion levels, and sources (i.e., country) for this criterion is challenging and relies on multiple sources to help create a more robust and accurate assessment.

Data to inform this assessment were pulled from academic literature, audits of the five certified Aquaculture Stewardship Council (ASC) shrimp farming companies in Indonesia[100] (PT Ketah Makmur, CP Prima, CP Bahari, PT Delta Guna Sukses, and PT Surya Windu Kartika), three feed manufacturers (PT Grobest, which provided three feed formulations, PT De Heus, and PT Central Proteina Prima), and the Indonesian Feedmills Association (GPMT). All sources of marine ingredients were derived from personal communication with PT Central Proteina Prima (CPP) and PT Grobest and inform the evaluation of Factor 5.1b and Factor 5.3. From the academic literature, ingredient lists and inclusion levels were derived from studies conducting feed trials on whiteleg shrimp in Indonesia. Because the control diets were designed to mimic commercial feeds on the Indonesian market, they are used here (Novriadi, R. et al., 2021, 2022a, 2022b, 2022c).[101]

Table 19 shows the estimated feed profile, including ingredients, the inclusion levels, inclusion level range, the total number of data points for each ingredient, and the number and type of source where data are pulled from. Note that a single source can provide multiple data points for a single ingredient, because inclusion levels are commonly provided as a range. The ingredients listed were selected because they are the most frequently cited across the various sources and therefore had the greatest number of data points (see Data Points column).

The Inclusion Level column is the calculated average across all the data sources provided, which (depending on the ingredient) had varying ranges (see the Range column). To determine a final inclusion level for each ingredient (and a total formulation of 100.0 %), some assumptions or adjustments were made (all figures are percentage inclusion levels):

- The fishmeal and fish oil whole fish and by-product inclusion levels were estimated by first calculating the average for all data provided for each. The results for fishmeal were whole fish, 3.5, and by-products, 6.8, which totals 10.3. The estimated total fishmeal inclusion level is 12.6, so the difference between 12.6 and 10.3, 2.3, was split evenly between whole fish and by-products for fishmeal. For fish oil, there was no reported whole fish use, and the estimated by-product inclusion level, 2.6, was reduced slightly to match the estimated total fish oil, 2.5.
- All other ingredient types are the resulting average of the data provided, except rice bran, which was reduced slightly from 12.5 to 9.2 to help round out the total inclusion level of 100%.

---

[100] PT Ketah Makmur, https://www.asc-aqua.org/find-a-farm/ASC01553/
CP Prima (number of sites: 560), https://www.asc-aqua.org/find-a-farm/ASC01047/
CP Bahari, https://www.asc-aqua.org/find-a-farm/ASC00958/
PT Delta Guna Sukses, https://www.asc-aqua.org/find-a-farm/ASC00809/
PT Surya Windu Kartika, https://www.asc-aqua.org/find-a-farm/ASC01514/

[101] This series of feed studies by Novriadi et al. was conducted at the Department of Aquaculture, Jakarta Technical University of Fisheries, in Indonesia.

Table 17: Feed profile estimate from a range of data sources, and explanation of the data sources.

Feed Profile Estimate								
Ingredients	**Inclusion Level**		**Range**		**Data Points**	**Source***		
	Average	**Final**	Low	High		**Feed Suppliers (n = 3)**	**ASC Audits (n = 5)**	**Literature (n = 4)**
Fishmeal	12.6	**12.6**	5.0	35.0	25.0	3.0	5.0	4.0
FM whole fish	3.5	**4.7**	0.0	10.0	6.0	2.0		
FM by-products	6.8	**7.9**	1.0	15.0	8.0	3.0		
Fish oil	2.5	**2.5**	0.9	5.7	21.0	3.0	5.0	4.0
FO whole fish	0.0	**0.0**	0.0	0.0	4.0	2.0		
FO by-products	2.6	**2.5**	1.0	5.0	8.0	2.0		
Vegetable ingredients			30.0	75.0	9.0	3.0		
Soybean meal	31.7	**31.7**	20.0	44.9	19.0	3.0	3.0	4.0
Corn gluten meal	8.0	**8.0**	6.0	10.0	3.0	1.0	3.0	2.0
Wheat flour	23.3	**23.3**	15.0	35.0	19.0	3.0	3.0	4.0
Rice bran	12.5	**9.2**	5.0	20.0	6.0	1.0		
Land animal ingredients			0.0	25.0	7.0	3.0		
Poultry by-product meal	7.7	**7.7**	0.0	20.3	13.0	1.0	3.0	2.0
Other	5.0							
Vitamins & minerals	5.7	**5**	0.0	10.0	9.0	3.0		
Total		**100.0**						

* Note: missing values mean that no values were given from the data sources.

Note that the totals of all vegetable ingredients, 72.2, and land animal ingredients, 7.7, are within the ranges of the data provided, while vitamins and minerals are slightly higher, 5.7, and are reduced to 5.0.

Although this method for estimating the feed ingredient inclusion level is imprecise, it is considered to be a sufficiently representative feed profile from all the data provided across the various sources and is used for the following factors.

Factor 5.1—Wild Fish Use

Factor 5.1 combines an estimate of the amount of wild fish used to produce farmed shrimp with a measure of the sustainability of the source fisheries. Table 21 shows the data used and the calculated forage fish efficiency ratio (FFER) for fishmeal and fish oil.

Factor 5.1a—forage fish efficiency ratio (FFER)

The forage fish efficiency ratio (FFER) for aquaculture systems is driven by the feed conversion ratio (FCR), the amount of aquatic (typically marine) animals used in feeds, and the source of the marine ingredients (i.e., the use of fishmeal and fish oil from processing by-products or from whole fish targeted by wild capture fisheries).

FCR is the ratio of feed given to an animal per weight gained, measured in mass (e.g., FCR of 1.4:1 means that 1.4 kg of feed is required to produce 1 kg of fish). It can be reported as either biological FCR (bFCR), which is the straightforward comparison of feed given to weight gained, or economic FCR (eFCR), which is the amount of feed given per weight harvested (i.e., accounting for mortalities, escapes, and other losses of otherwise-gained harvestable fish). The Seafood Watch Aquaculture Standard utilizes the eFCR.

To calculate a representative eFCR for intensive and semi-intensive *L. vannamei*, data were gathered from academic literature, audits of three ASC-certified shrimp farming companies in Indonesia (PT Ketah Makmur, PT Delta Guna Sukses, and PT Surya Windu Kartika), and personal communications with feed manufacturers (PT Central Proteina Prima, PT De Heus, PT Grobest), industry stakeholders (GQSP Indonesia, researchers, JALA Tech), and regulatory agencies (MMAF). The resulting eFCR estimate for *L. vannamei* is 1.4 for semi-intensive and intensive production systems (see Table 20 for the eFCR values and the source references).

Table 18: eFCR values and the resulting calculated average for both semi-intensive and intensive production systems in Indonesia for *L. vannamei*.

eFCR Estimate			
Background	**Source**	**Range**	
		Low	**High**
Aquaculture Stewardship Council	Survey of farms in Situbondo	1.3	
Researcher	*Anonymous*	1.2	1.4
Researcher	*Anonymous*	1.2	1.7
Indonesian Feed Supplier and Hatchery	PT Central Proteina Prima	1.4	
Non-Government Organization	Global Quality and Standards Program Indonesia	1.2	1.5
Data & Technology Business	JALA Tech	1.6	1.8
Indonesian Regulatory Agency	MMAF	1.3	
Researcher	*Anonymous*	1.2	1.4
Indonesian Feed Manufacturer	PT De Heus	1.5	
Indonesian Feed Manufacturer	PT Grobest	1.3	
Indonesian Feed Manufacturer	PT Grobest	1.5	
Indonesian Feed Manufacturer	PT Grobest	1.7	
Academic Literature	Henrickson, 2019	1.5	
Academic Literature	Supono 2021	1.3	1.5
Academic Literature	Boyd et al. 2021a	1.4	
Aquaculture Stewardship Council Audit	PT. Delta Guna Sukses	1.2	
Aquaculture Stewardship Council Audit	PT Ketah Makmur	1.5	
Aquaculture Stewardship Council Audit	PT. Delta Guna Sukses	1.1	
Aquaculture Stewardship Council Audit	PT. Delta Guna Sukses	1.2	
Aquaculture Stewardship Council Audit	PT Surya Windu Kartika	1.1	
	Average	1.4	

The total fishmeal and fish oil inclusion levels, along with the associated whole fish and by-product inclusion levels for each, are discussed at the beginning of this criterion. The source fisheries and their sustainability are discussed in Factor 5.1b. Table 21 shows the calculated FFER values associated with the eFCR and fishmeal/fish oil inclusion rates for *L. vannamei*. The standard yield values (i.e., the amount of fishmeal and fish oil obtained per unit of whole fish, from Tacon and Metian, 2008) have been used.

Table 19: *L. vannamei* fishmeal and fish oil inclusion levels from whole fish and by-product sources, eFCR values, and calculated FFER values.

Parameter	Data
Fishmeal inclusion level	**12.6%**
Percentage of fishmeal from whole fish	4.65%
Percentage of fishmeal from by-products	7.95%
Fishmeal yield (from wild fish)	22.5%
Fish oil inclusion level	**2.5%**
Percentage of fish oil from whole fish	0%
Percentage of fish oil from by-products	2.5%
Fish oil yield	5%
Economic Feed Conversion Ratio (eFCR)	**1.4**
Calculated Values	
Forage **Fish Efficiency Ratio (FFER) (fishmeal)**	0.31
Forage **Fish Efficiency Ratio (FFER) (fish oil)**	0.03
Assessed FFER	**0.31**

From first principles, these values mean that, in feed-dependent semi-intensive and intensive systems, 0.31 MT of wild fish are required to provide sufficient fishmeal to produce 1 MT of farmed *L. vannamei*. The low FFER value is buoyed by the high inclusion (63%) of by-products, which is an estimate.

Factor 5.1b—sustainability of the source of wild fish

This factor evaluates the sustainability of the fisheries supplying fishmeal (FM) and fish oil (FO) for Indonesian whiteleg shrimp grow-out feed. Broad industry trends suggest that Indonesia is a large importer of fishmeal and fish oil. Despite large volumes of domestic wild fisheries, Indonesia imports roughly 65–80% of its fishmeal and fish oil (Sarifin, M.S., 2017) (Minapoli, 2021). In 2018, fishmeal imports were roughly 160,000 MT (Luhur, et al., 2021). From 2016 to 2018, the most significant exporters of fishmeal to Indonesia were the United States, South Korea, Thailand, and Vietnam, though the market share of each country and the species type/method are not detailed and are largely driven by current prices (Luhur, et al., 2021). Because of the reliance on imports of fishmeal and fish oil, there is a growing interest in reducing import dependence (Sarifin, M.S., 2017) (Minapoli, 2021) (Luhur, et al., 2021).

Regionally, Thailand and Vietnam are dominant fishmeal producers and account for ≈90% of Southeast Asia's fishmeal production from 2005 to 2020 (SEASOFIA, 2022). "The majority of Thai and Vietnamese fishmeal is utilized domestically, with the remainder exported to China, Japan, India, Taiwan, Bangladesh, and other AMSs [Asian Member States; e.g., Indonesia]" (SEASOFIA, 2022). Much of the production, up to 75%, is sourced from by-products of tuna, small pelagics, and (farmed) *Pangasius* (SEASOFIA, 2022), while the balance is likely partly from multispecies fisheries (e.g., trawl, seining, stow nets, bag nets), where the majority of fish are for fishmeal, though fish for direct human consumption are the primary drivers of the fishing activity (Leadbitter, D., 2019).

There is concern about illegal, unregulated, and unreported (IUU) fisheries in Southeast Asia. This includes the dominant fishmeal producers of Vietnam and Thailand, and there are ongoing efforts to eliminate these practices. The progress in Thailand is especially notable (see the Seafood Watch assessment of Thailand farmed shrimp). As stated, Indonesia's domestic fisheries supply an estimated 20–35% of the domestic fishmeal and fish oil demand. Although there is no direct evidence linking Indonesia's domestic fishmeal or fish oil production to IUU fishing, it is important to note that within Indonesia's exclusive economic zone (EEZ) are the Arafura and Natuna Seas; both are considered IUU hotspots (Leadbitter, D., 2019). To monitor vessels and combat the risk of Indonesian fishing vessels operating as IUU fisheries, the Indonesian government conducts air surveillance, partners with the Global Fishing Watch, and developed an online platform to monitor vessel management system (VMS) transmitters (SEASOFIA, 2022). Despite these efforts, the IUU Fishing Risk Index ranks the risk of IUU from Indonesia as very high, ranking it the sixth-highest risk among all 152 countries evaluated, and Indonesia has been carded by the EU and identified by NOAA for IUU fishing.[104]

Despite repeated attempts to connect with feed manufacturers in Indonesia (of which only three were successfully contacted), there are limited data available to robustly determine the species, inclusion, and source fisheries of marine ingredients for Indonesian shrimp feed. Two feed manufacturers (PT Grobest and PT Central Proteina Prima) provided partial source fishery data, but some key information was not detailed, such as the fishing method (gear type), location of fishing (FAO regions), or documentation of certification claims. Nevertheless, with a combined market share of Indonesian feed manufacturing of > 30%, these companies' data do provide some insight into marine ingredient sources and their sustainability, and broadly follow some of the trends previously discussed.

Table 22 summarizes the marine ingredient sources, reflecting the details of the data provided and the resulting Factor 5.1b scores. Fishmeal comprises skipjack and yellowfin tuna by-products along with anchovies and sardines. Fish oil is derived from skipjack and yellowfin tuna by-products and Chilean farmed Atlantic salmon. A discussion follows of each entry in Table 22 and the justification for each Factor 5.1b score .

Sustainability score of wild-caught skipjack tuna

Skipjack by-products are reportedly used for fishmeal and fish oil, with estimated inclusion levels of 3.95% and 0.83%, respectively. Skipjack by-products are MarinTrust certified, which is confirmed from the MarinTrust website and supporting documentation.[105] Key information describing the fishery, such as fishing methods and location (i.e., FAO region), were not available, which made any objective sustainability claims of the source fishery challenging. Seafood Watch (SFW) ratings[106] for skipjack tuna

---

[104] https://iuufishingindex.net/profile/indonesia

[105] https://www.marin-trust.com/sites/marintrust/files/approved-raw-materials/IND04_Indonesia_Skipjack%20tuna_FAO%2071_Initial_April_2024.pdf

[106] https://www.seafoodwatch.org/globalassets/sfw-data-blocks/reports/t/seafood-watch-tuna-swordfish-wcp-28444.pdf

fished in the West Central Pacific Ocean (WCPO) include red (floating object purse seine), yellow (unassociated purse seine), and green (handlines and hand-operated pole and lines, and trolling lines).

Therefore, Indonesian skipjack by-products are confirmed as MarinTrust certified (score of 4); however, the unknown fishing methods and fishing locations could include a SFW red-rated fishery, which drives the score (score 2). The resulting sustainability score is an intermediate 3 out of 10.

Sustainability score of wild-caught yellowfin tuna
Yellowfin by-products are reportedly used for fishmeal and fish oil, with estimated inclusion levels of 3.95% and 0.83%, respectively. Yellowfin tuna by-products are MarinTrust certified, which is confirmed from the MarinTrust website and supporting documentation.[107] Key information describing the fishery, such as fishing methods and location (i.e., FAO region), were not available, which made any objective sustainability claims of the source fishery challenging. SFW ratings[108] for yellowfin tuna fished in the West Central Pacific Ocean (WCPO) include red (drifting long lines, floating object purse seine), green (handlines and hand operated pole and lines, trolling lines), and yellow (unassociated purse seine).

Therefore, Indonesian skipjack by-products are confirmed MarinTrust certified (score of 4); however, unknown fishing methods and fishing locations could include a SFW red-rated fishery, which drives the score (score 2). The resulting sustainability score is 3 out of 10.

Sustainability score of wild-caught anchovy
Anchovy is included as whole fish for fishmeal, with an estimated inclusion level of 2.35%. Although the fishing method was not provided, it is assumed that anchovy is caught from industrial fleet purse seines. Anchovy is from the Northern Central Peruvian stock, and the SFW rating is green. The resulting sustainability score is 10 out of 10.

Sustainability score of wild-caught sardine
Sardine is included as whole fish for fishmeal, with an estimated inclusion level of 2.35%. The fishing method was not provided, nor was a precise location (what was shared was “the Middle East”). Given this limited information, the sustainability of the source ingredient could not be identified through certifications or SFW ratings, and is effectively unknown. The resulting sustainability score is 2 out of 10.

Sustainability score of farmed Chilean Atlantic salmon
Chilean farmed Atlantic salmon by-products are included for fish oil, with an inclusion level of 0.83%. There are red and yellow SFW ratings[109] for farmed Chilean Atlantic salmon, but further details, such as the location of farmed origin, were not made available. Therefore, it is assumed that the by-products are sourced from a red-rated region, and the resulting sustainability score is 2 out of 10.

Calculating the sustainability of source fishery scores

---

[107] https://www.marin-trust.com/sites/marintrust/files/approved-raw-materials/IND03_Indonesia_Yellowfin%20tuna%20_FAO%2071_Initial_April_2024.pdf

[108] https://www.seafoodwatch.org/globalassets/sfw-data-blocks/reports/t/seafood-watch-tuna-swordfish-wcp-28444.pdf

[109] https://www.seafoodwatch.org/recommendations/search?query=%3Aspecies%3BAtlantic%20salmon%3Acountry%3BChile

To calculate a single-source fishery sustainability score across all marine ingredients, the methodology and equations used are detailed in the Seafood Watch Aquaculture Standard—Appendix 3, Scenario 1: Single Feed Type (see Eq. 5–7). Note that this methodology is intended to recognize the use of by-product ingredients in aquaculture feeds (as is the case here), but not entirely ignore any sustainability concerns of the associated fisheries or aquaculture; therefore, by-products are included in the scoring at a 5% ratio. As a result, the final score for Factor 5.1b—sustainability of the source of wild fish is driven largely by the whole fish sources, and is 5.53 out of 10.

Combining the score for Factor 5.1a—forage fish efficiency ratio (FFER), 0.31, with Factor 5.1b—sustainability of the source of wild fish, 5.53 out of 10, results in a score for Factor 5.1—Wild Fish Use of 7.40 out of 10 for *L. vannamei*.

Table 20: Marine ingredient sources and the resulting Seafood Watch (SFW) sustainability score.

Product	Species	Type	Inclusion*	Country	Gear Type	Certifications	SFW Rating	F5.1b Score
Fishmeal	Skipjack	By-products	3.95%	Indonesia	Unknown	MSC, MarinTrust	Red	3
Fishmeal	Yellowfin	By-products	3.95%	Indonesia	Unknown	MSC, MarinTrust	Red	3
Fishmeal	Anchovy	Whole fish	2.35%	Peru	Unknown	MarinTrust	Green	10
Fishmeal	Sardine	Whole fish	2.35%	Middle East	Unknown	MSC	*None*	2
Fish Oil	Skipjack	By-products	0.83%	Indonesia	Unknown	MSC, MarinTrust	Red	3
Fish Oil	Yellowfin	By-products	0.83%	Indonesia	Unknown	MSC, MarinTrust	Red	3
Fish Oil	Atlantic Salmon	By-products	0.83%	Chile	Unknown	*None*	Red	2

*Note: the inclusion levels were calculated taking the total fishmeal or fish oil whole fish or by-product estimates from Table 19 and dividing by the number of entries here. For example, fishmeal by-products inclusion was estimated as 7.95%, which was divided by the two marine ingredient sources listed (skipjack and yellowfin), resulting in a marine ingredient source inclusion of 3.95% for both species.

Factor 5.2—Net Protein Gain or Loss

The protein content of *L. vannamei* feed was determined by calculating the average from values gathered from literature (Boyd et al. 2021a) (Novriadi, R., et al., 2021a,b; 2022a,b,c), feed manufacturers (as stated), a feed mill association (GPMT), ASC audits (as stated), and through surveys (ASC referencing farms in Situbondo). The values ranged from 20.5% to 40.2%, with an average of 33.6%, which is used here. The protein content of whole harvested *L. vannamei* shrimp is 17.8% (Boyd et al., 2007) and the eFCR value of 1.4 was used as noted. From these values, it is estimated that there is a net loss of 62.2% of protein due to the high protein content of feed (Table 23). The resulting score for Factor 5.2 is 3 out of 10.

Table 23: The parameters used and their calculated values to determine the protein gain or loss in the production of farmed *L. vannamei* in semi-intensive and intensive systems.

Parameter	**Data**
Protein content of feed (%)	33.6
Protein content of whole harvested shrimp (%)	17.8
Economic Feed Conversion Ratio	1.4
Total protein INPUT per ton of farmed shrimp (kg)	470.4
Total protein OUTPUT per ton of farmed shrimp (kg)	178.0
Net protein loss (%)	-62.2
Seafood Watch Score (0-10)	**3**

Factor 5.3. Feed Footprint

This factor is an approximation of the embedded global warming potential (GWP; kg CO_2-eq including land-use change [LUC]) of the feed ingredients required to grow 1 kg of farmed seafood protein. This calculation is performed by mapping the ingredient composition of a typical feed used against the Global Feed Lifecycle Institute (GFLI) database[110] to estimate the GWP of 1 MT of feed, followed by multiplying this value by the eFCR and the protein content of whole harvested seafood.

Table 24 shows the ingredient categories selected from the GFLI database. Because of the licensing agreement, the specific values for each ingredient from the GFLI database are not reproduced here, but the calculated value per MT of feed for each ingredient is shown. The GFLI database did not have exact matches for some of the ingredients and/or the country of origin, so some assumptions are made. Each ingredient category and any assumptions are listed as follows.

It should be noted that the ingredient types and the country of origin considered for vegetable ingredients, terrestrial, and "other" are derived from literature, feed companies, and ASC audits (see Table 19). The sources of information and their representativeness are not evaluated as cautiously as for marine ingredients, because they have less impact on the scoring (i.e., nonmarine ingredients are only considered in Factor 5.3) and there is some convergence on the ingredient type and origin across the separate sources.

Marine Ingredients

- A match within the GFLI database for anchovy caught from Peru was found and selected.
- The country of origin and species are known for other marine ingredients (e.g., whole fish and by-products for fishmeal and/or fish oil), but the GFLI database did not have an exact match for skipjack, yellowfin, sardine, or Atlantic salmon by-products. The GFLI database entries that were selected and their justifications are:
    - Skipjack and yellowfin tuna wild-caught from Indonesia (fishmeal and fish oil)
        - Since the specific species and country of origin were not listed within the GFLI database, the closest neighboring country's aggregate of fishmeal and fish oil—China and Japan, respectively—was selected as a substitute.
    - Sardine wild-caught from the Middle East (fishmeal)
        - Because the specific species and country of origin were not listed within the GFLI database, a similar entry in a region (Europe) and species (sardine) was selected.
    - Farmed Atlantic salmon by-products from Chile (fish oil)
        - The GFLI database contains an entry for fish oil from Chile, so it was selected.

Vegetable Ingredients

- Soybean meal is the average from the country of origin stated from the various sources—Argentina (e.g., PT De Heus, PT Grobest, Novriadi et al. 2022) and Brazil (e.g., PT De Heus, ASC Surya Windu, 2022).
- Wheat flour is sourced from Indonesia (e.g., PT De Heus, Novriadi et al. 2022a, Novriadi et al. 2021, ASC Surya Windu, 2022) and Ukraine (PT Grobest), but neither country is listed in the GFLI database, so the European average was selected.

---

[110] http://globalfeedlca.org/gfli-database/gfli-database-tool/

- Both corn gluten meal and rice bran were sourced from Indonesia (Novriadi et al., PT Grobest 2022), but Indonesia is not listed in the GFLI database for either product. So for rice bran, the only listed option, Canada, is used. For corn gluten meal, the global average (GLO) was selected.

Terrestrial Animal Ingredients

Poultry is sourced from the United States (e.g., PT De Heus, PT Grobest, Novriadi et al. 2022) as by-products, but the European average was the only relevant option in the GFLI database.

Other

More granular information of the ingredient type was not provided beyond vitamins and minerals, and the country of origin, Taiwan, was not listed in the GFLI database. So the only option, European average, was selected.

Table 24: Estimated embedded global warming potential of 1 MT of a typical Indonesian semi-intensive *L. vannamei* feed. Note: the sources used here are not specific to Indonesian shrimp feeds but are proxies, as described in the text.

Feed ingredients (≥ 2% inclusion)	GWP (incl. LUC) Value (kg CO_2 eq/ton product)	Ingredient inclusion %	kg CO_2 eq/ MT feed
Fishmeal	Fishmeal, from Anchoveta, at processing/PE Economic S	12.6	139.80
	Fishmeal, from European pilchard (sardine), at processing/NO Economic S		
	Fishmeal, at processing/CN Economic S		
Fish oil	Fish oil, at processing/CL Economic S	2.5	19.34
	Fish oil, at processing/JP Economic S		
Soybean meal	Soybean meal (solvent), at processing/AR Economic S	31.7	1,339.12
	Soybean meal (solvent), at processing/BR Economic S		
Wheat flour	Wheat flour, at processing/RER Economic S	23.3	140.96
Corn gluten meal	Maize gluten meal dried, at processing/GLO Economic S	8.0	90.07
Rice bran	Rice bran meal, at processing/CN Economic S	9.2	32.45
Poultry by-products	Animal meal, poultry, at processing/RER Economic S	7.7	61.41
Vitamins and Minerals	Total minerals, additives, vitamins, at plant/RER Economic S	5.0	2.27
	Sum of total	**100.0**	**1,825.45**

As shown in Table 24, the estimated embedded GWP of 1MT of a typical Indonesian semi-intensive and intensive *L. vannamei* feed is 1,825.45 kg CO_2-eq, and it is driven by the substantial inclusion of soybean meal. Considering a whole harvest shrimp protein content of 17.8% for *L. vannamei* and an eFCR of 1.4, it is estimated that the feed-related GWP of 1 kg semi-intensive and intensive farmed *L. vannamei* protein is 14.34 kg CO_2-eq. This results in a score of 6 out of 10 for Factor 5.3—Feed Footprint.

Conclusions and Final Score

There are some indications that feed may occasionally be used in extensive *P. monodon* and *L. vannamei* production, but overall, it is assumed to be insignificant for the purposes of this assessment. Therefore, the final score for Criterion 5—Feed for *P. monodon* and *L. vannamei* in extensive systems is 10 out of 10. For *L. vannamei* in fed semi-intensive and intensive systems, a variety of sources of feed information was used, including from farming companies, feed mills, certified farms, and academic literature. Nevertheless, information differentiating the specific feed characteristics of the two systems (e.g., eFCR, protein content, and ingredients) was not robustly available. Therefore, the assessment was completed for *L. vannamei* independent of the production system, and the score applies to both semi-intensive and intensive production.

Using the available data, *L. vannamei* grown in intensive and semi-intensive production systems are calculated to have a forage fish efficiency ratio (FFER) of 0.31. This means that, from first principles, 0.31 MT of wild fish would need to be caught to produce 1.0 MT of farmed shrimp. Data describing marine ingredient sources were limited, but some information, though missing key insights such as the fishing method and fishing location (e.g., FAO region), was made available to allow for a limited source fishery sustainability evaluation. The fishmeal and fish oil marine ingredient sources were derived from by-products (e.g., skipjack tuna, yellowfin tuna, and farmed Chilean Atlantic salmon) and whole fish (sardine and anchovies), resulting in a score for Factor 5.1b—source fishery sustainability of 6 out of 10. The combined scores for Factor 5.1a (0.31) and Factor 5.1b (6 out of 10) result in a score for Factor 5.1—Wild Fish Use of 7 out of 10 for *L. vannamei* in intensive and semi-intensive systems.

With an estimated average feed protein content of 33.6% for *L. vannamei* in intensive and semi-intensive systems, there is a substantial net protein loss of 62.2%, which results in a score for Factor 5.2—Net Protein Gain or Loss of 3 out of 10. The Feed Footprint (Factor 5.3) was estimated as 1,825.45 kg CO_2-eq per MT of shrimp feed, and is driven by the substantial inclusion of soybean meal. Considering a whole-harvest shrimp protein content of 17.8% for *L. vannamei* and an eFCR of 1.4, it is estimated that the feed-related GWP of 1 kg of semi-intensive and intensive farmed *L. vannamei* protein is 14.34 kg CO_2-eq. This results in a score of 6 out of 10 for Factor 5.3—Feed Footprint. Combined, the final score for Criterion 5—Feed for *L. vannamei* (in both semi-intensive and intensive production systems) is 5.95 out of 10. (See the Seafood Watch Aquaculture Standard for full details of the scoring calculations.)

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: preventing population-level impacts to wild species or other ecosystem-level impacts from farm escapes.

Criterion 6 Summary

	L. vannamei		***P. monodon***	
Escape parameters	**Value**	**Score**	**Value**	**Score**
Intensive and Semi-Intensive				
F6.1 System escape risk	3			
F6.1 Recapture adjustment	0			
F6.1 Final escape risk score		3		
F6.2 Competitive and genetic interactions		6		
Extensive				
F6.1 System escape risk	0		0	
F6.1 Recapture adjustment	0		0	
F6.1 Final escape risk score		0		0
F6.2 Competitive and genetic interactions		6		8
Intensive C6 Escape Final Score (0–10)		4		
Semi-Intensive C6 Escape Final Score (0–10)		4		
Extensive C6 Escape Final Score (0–10)		3		4

Brief Summary

For *L. vannamei* on intensive and semi-intensive farms, the escape risk that is associated with flooding (i.e., farm location) and the daily exchange rate (3–10%) is considered to be slightly lower than that for extensive farms, but is still high, and the score for Factor 6.1—Escape Risk is 3 out of 10. The escape risk of *L. vannamei* on extensive production systems is considered to be high, because they rely on tidal water exchanges and must be located in areas that are considered at high risk of flooding. As a result, Factor 6.1—Escape Risk scores 0 out of 10 for extensive systems.

A review of literature surrounding competitive and genetic interactions of escape farmed shrimp with wild species revealed that there is no evidence of nonnative *L. vannamei* establishing viable populations anywhere in the world, and it is concluded that, although *L. vannamei* is likely to be present in the wild in Indonesia, it is not considered to be established and is highly unlikely to establish viable populations. Thus, the score for Factor 6.2—Competitive and Genetic Interactions for *L. vannamei* is 6 out of 10.

Combined, the final score for Criterion 6—Escapes for *L. vannamei* intensive and semi-intensive production systems is 4 out of 10. With a higher risk of escape, *L. vannamei* grown in extensive systems has a final Criterion 6—Escapes score of 3 out of 10.

Because *P. monodon* on farms originates from wild-caught broodstock, in the event of an escape, it is unlikely to present significant competitive or genetic risks to wild populations, given its native status and high genetic similarity to wild conspecifics. The score for Factor 6.2—Competitive and Genetic Interactions is 8 out of 10. Combined, the score for Criterion 6—Escapes for *P. monodon* in extensive production systems is 4 out of 10.

Justification of Rating

Factor 6.1—Escape Risk

Farmed shrimp can escape in various ways, including during water exchanges, harvests, pond cleaning, floods, from hatcheries, during transport, and intentional releases (Lusiastutiet al., 2021 and references therein). There are no readily available data on escape events or on escape quantities (either in numbers or weight) in Indonesia. There is some guidance readily available for escape prevention (i.e., IndoGAP CBIB) but there is no monitoring programs for escapes. The guidance from IndoGAP CBIB includes principles for siting: avoid siting in areas where flooding may occur, which is also evaluated during the permitting of farms (see Habitat criterion Factor 3.2a), and pond embankment heights must be 0.5 m taller than the highest tide (BSN, 2022). But the percentage of compliance to IndoGAP CBIB certification across Indonesia is uncertain, while enforcement of farm siting during the permitting phase appears limited. Therefore, the escape risk is determined based on what is known about typical farm practices, the locations of farms, and pond design, as well as the climatic risk (e.g., risk of flooding).

Regarding the flood risk at the country level, Indonesia's climate is classified as largely tropical and tropical monsoon (pers comm, FUI, Anonymous, CPP, 2021) (UN World Bank, 2021). Typical rainfall patterns vary by season, with the dry season from May through October and the wet season from November to April. Rainfall may increase during La Niña events, while it may decrease during El Niño. The impact of severe rainstorms can be devastating and may result in flooding events that cause significant economic damage and the loss of life.[111] On average from 1980 to 2020, there were 213 flooding events per year in Indonesia, accounting for 43% of all annual natural hazards in the country over this period (UN World Bank, 2021). The UN World Bank considers that the combination of intensifying rainfall trends during the wet season and the rise in sea level due to climate change suggests that the risk of flooding will likely persist[112] or increase in the present and near future (UN World Bank, 2021).

<u>Extensive: *P. monodon* and *L. vannamei*</u>

There does not appear to be any readily available guidance or regulations to minimize farm escapes from extensive ponds, besides the CBIB guidance discussed (i.e., pond embankment height and farm siting). An important initial mitigation technique against flooding is farm siting. In general, it can crudely be considered that, if a coastal farm is located > 4 m above sea level, it will not have a risk of flooding; whereas, at < 2.5 m, the flood risk increases (pers comm, Widigo, Wibowo, 2023). Data describing the height above sea level of shrimp ponds are not readily available, but because of the reliance on tidal

---

[111] Twelve significant flooding events in Indonesia: https://en.wikipedia.org/wiki/Category:Floods_in_Indonesia

[112] *Living amid flood in Indonesia, unable to leave* by Dita Alangkara and Victoria Milko, August 31, 2022 https://apnews.com/article/floods-indonesia-java-climate-and-environment-bc4433924c7815e4d913f868f922c201

water exchanges, the traditional development location of extensive farms is in low-lying coastal areas, making them vulnerable to flooding events (pers comm, Desyana, 2023). As stated, flooding appears frequently in Indonesia; for example, in September 2022, in South Sulawesi, a flood occurred affecting at least 50 ha of shrimp farms and led to ≈300 million rupiah (IDR3 million = ≈USD19,083) in losses (pers comm, Desyana, 2023).

Typical farm practices include measures to minimize the risk of shrimp escaping, because it is an obvious and undesired economic loss. To help with pond water height fluctuation (i.e., tides, rainfall events), farmers will evaluate site characteristics along with local conditions and create the appropriate pond dike height when building the farm, and control pond water height during the production cycle with sluice gates (pers comm, Anonymous, 2021). Farmers use nets and screens to minimize the escape risk by placing screens in front of the discharge point (pers comm, Faturakhmat, 2023), which is especially helpful during more vulnerable moments such as water exchanges at harvest, and a screen is also placed at the discharge point of the drainage canal, if used (pers comm, Sukenda and Kokarkin, 2024). But less is known about the details in terms of the use of appropriate mesh sizes, the use of double screens at high-risk events such as harvest, and particularly their maintenance. Also, early preparation for flooding events is important. There are warnings of possible flooding from long-term forecasts communicated by government agencies, and these may result in farmers stocking at lower densities and eventually harvesting before flooding events, such as a partial or whole harvest, but it all depends on the risk level perceived by the farmer (pers comm, Susanto, 2023) (pers comm, MMAF, 2021).

Despite the implementation of escape mitigation practices, their effectiveness is uncertain because monitoring of farm escapes in the wild is not conducted and does not appear to be a concern of the government. According to GQSP UNIDO and MMAF (pers comm, 2021), escape events are reportedly rare, while reports of escape events from farms are also not systematically or centrally recorded. In the event of an escape event, there is no evidence or data on any recapture efforts or their success, and no recapture adjustment is applied here.

Despite the opinions of GQSP UNIDO and MMAF (as stated), considering the location of the extensive production systems, the escape risk is considered here to be high. It is challenging to understand how the widely reported frequency and severity of floods in Indonesia may be decoupled from affecting extensive farms, because they exist within the floodplains. Despite the apparent high risk, there are only two documented cases of flood events affecting extensive shrimp farms that could be readily found. Research is needed to help put the escape risk in context (i.e., abundance, frequency, location, and magnitude) of these extensive systems. Because there is no monitoring or reporting of escapes, the score for Factor 6.1—Escape Risk is based on the siting of farms in flood-prone areas. The score for Factor 6.1—Escape Risk is 0 out of 10 for extensive farms.

Semi-Intensive and Intensive: *L. vannamei*

Additional guidelines and regulations relating to escapes for intensive or semi-intensive systems were not readily available, but like for extensive systems, farm practices and design are implemented to limit escapes from ponds. The use of nets or screens for all inlets and outlets is common (pers comm, GQSP UNIDO, CPP, 2021), and if/when a sluice gate is used during harvests and water changes, a netting or screen is used to limit escapes as well (pers comm, GQSP UNIDO, 2021). Pond water levels are controlled through the combination of water exchanges, sluice gates, and the height of pond walls. Farmers actively manage water level heights and pond bank heights to limit the shrimp escapement risk (pers comm, GQSP UNIDO, 2021) and monitor for escapes in canals and sediment ponds (pers comm, Sukenda and Kokarkin, 2024). For example, if there is severe rain/flooding expected, farmers may raise the pond wall heights (e.g., add sandbags), harvest crops immediately, and/or close all water inlets (pers comm, MMAF, 2021).

The frequency, severity, or risk of flood events affecting semi-intensive and intensive farms is reportedly lower than for extensive farms, but direct evidence is limited. These farms are more intensive in production and may have the potential for greater control, so the design and nature of the ponds allow for a reduced flooding risk, while these farms are located in slightly less flood-prone areas (i.e., at higher elevations) because they are do not rely on tidal exchange for water distribution (pers comm, FUI, MMAF, CPP, 2021) (pers comm Sukenda and Kokarkin, 2024). Evidence of flooding events on shrimp farms is not frequently reported. A news article was found describing significant loss of *L. vannamei* from a farm in East Java due to a flooding event in June 2013, amounting to about 5 tons of shrimp escaping from each pond (Tempo June 2013, *Shrimp Farmers Lost Billions Due to Flood*). Further details such as the location of all shrimp farms and classification by shrimp species and intensity would help to add nuance to the risk of flooding, but these data are not readily available, thus limiting the analysis and conclusion.

Regarding the presence of *L. vannamei* in the wild as an indicator of escapes from farms, this species has been detected in the wild beyond its native range in several countries (United States, Thailand, Venezuela, Brazil, Puerto Rico, Mexico, Philippines, and India) (De Silva et al., 2021, and references therein), but there is no evidence of it being caught or otherwise detected in significant numbers in the wild in Indonesia besides one study published in 2007 (Puspasari and Suryandari, 2007—see details in Factor 6.2). The lack of evidence of escapes found in the wild may be due to limited observational efforts or research, because there is limited insight on this matter in the literature. But some farmers do check discharge receiving waters for any escapes, to evaluate escape mitigation effectiveness, but any observations are not centrally reported or mandated (pers comm, GQSP UNIDO, 2023).

Overall, the escape risk due to flooding is considered to be slightly lower than for tidally exchanged, extensive farms. It appears that semi-intensive and intensive farms implement practices similar to those in extensive farms to minimize escapes (e.g., screens, high pond embankments, harvests before flooding events), but are less likely to be located primarily within the floodplain. Still, given how close farms have been sited to coastal areas—primarily within wetlands and mangroves (see Factor 3.1)—and how frequently flooding events occur in Indonesia, these systems are considered vulnerable to escape events. To help better characterize this risk, further insight such as the average pond height above sea level or more documentation of flooding events and impacts (or lack thereof) to farmers would be helpful, but is not readily available. There is one report of *L. vannamei* being detected in the wild in Indonesia in 2006, but there also does not appear to be any formal monitoring. Therefore, the risk for escapes from semi-intensive and intensive systems is primarily due to the perceived risk of the farm location (making these systems vulnerable to escape events) and the exchange rate of the ponds (> 3%). The resulting intermediate score for semi-intensive and intensive systems for Factor 6.1—Escape Risk is 3 out of 10.

Factor 6.2—Competitive and Genetic Interactions

<u>*P. monodon*</u>

For native species, the impact risk of competitive and genetic interactions in the environment from escapes is driven partly by the phenotypic traits of farm stock, so an examination of the source of stock (e.g., broodstock and/or juveniles) is required.

P. monodon is native to Indonesia, and because of its ready availability in the region, broodstock and post-larvae (commonly referred to as PL) have been historically sourced directly from the wild (Ardjosoediro and Goetz 2007). Because of overfishing and serious outbreaks of disease related to the use of wild post-larvae, the majority of *P. monodon* farms now rely solely on first-generation, hatchery-produced post-larvae (i.e., from wild broodstock parents) (FAO, 2005), so they exhibit high genetic similarity to wild conspecifics. Therefore, the likelihood of genetic impacts if they were to escape and interbreed with wild populations is quite low, particularly noting the findings of Wong et al. (2021) on the high genetic diversity in wild *P. monodon* populations. Although data are scant on the genetic impacts of escaped *P. monodon* on wild populations, a dated study in Thailand by Benzie (2000) found no conclusive evidence that aquaculture escapees had altered the genetic fitness of wild stocks of *P. monodon*. Similarly, Zhange et al. (2023) found that the stocking of hatchery-raised, native juvenile *P. japonicus* shrimp from wild-caught broodstock in the Beibu Gulf, South China Sea had no significant impact on the genetic diversity or variation of wild *P. japonicus*.

Regarding any potential competition between escaped *P. monodon* and wild shrimp, there is no information available to directly quantify the potential impacts. For example, as noted as follows for *L. vannamei*, it is likely that escaped *P. monodon* would have a similar diet type as several local shrimp species, but information regarding resource availability and regional stock statuses of *P. monodon* (or other penaeid species) in Indonesia is not particularly insightful or complete (see Criterion 8X—Source of Stock).

Overall, escaped farm stock derived from wild-caught *P. monodon* broodstock is unlikely to present significant competitive or genetic risks to wild populations, given its native status and high genetic similarity to wild conspecifics, and the score for Factor 6.2—Competitive and Genetic Interactions is 8 out of 10.

L. vannamei

L. vannamei is nonnative to Indonesia and received government approval for shrimp farming 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). As noted in Factor 6.1, *L. vannamei* shrimp has been detected in the wild in several countries beyond its native range, but little is known about its ecological impacts; for example, De Silva et al. (2021) note that whether the species will become predator or prey (or pathogen carrier) remains to be studied. The presence of *L. vannamei* in the wild may present competitive ecological risks for Indonesia's native shrimp species, including the commercially relevant *P. monodon*, though genetic risks are considered negligible, given the lack of other *Litopenaeus* species in Indonesia and significant failures in interspecific hybridizations of penaeid shrimps (Perez-Velazquez et al., 2010) (Ulate and Alfaro-Montoya, 2010).

Since the introduction in 2001, the *L. vannamei* domesticated stock has gone through numerous generations and been genetically selected for beneficial traits, such as growth rates and disease resistance, by the hatchery/broodstock industry both domestically and abroad; approximately 80% of the *L. vannamei* broodstock used in Indonesia is imported (pers comm, GQSP UNIDO, FUI, 2021).

Regarding the potential ecological impacts in the event of an escape of *L. vannamei*, the primary risks involve competition for food, predation, and acting as pathogen reservoirs (the latter is discussed in Criterion 7—Disease). While no research specific to Indonesia could be found, academic studies have examined the competitive risks that escaped *L. vannamei* poses to native shrimp populations (with special regard to diet and aggression) in other countries, notably Thailand. Researchers found that gut content data “indicated that *L. vannamei* ingested the same diet types (phytoplankton, appendages of crustacean zooplankton and detritus materials) […] in similar proportions to several local shrimp species” (Senanan et al., 2010). In addition, in laboratory studies, researchers found that *L. vannamei* exhibited more aggressive feeding behavior—approaching and capturing foods faster—than all other native Thai shrimp species collected, even *P. monodon* (Panutrakul et al., 2010). Further laboratory research on *L. vannamei* feeding behavior relative to native Thai shrimps have confirmed this result, with the species appearing to be nonselective in its prey choice and faster in identifying and consuming food, despite size class differences (Chanavich et al., 2016).

But in this same study, the competitive advantage of *L. vannamei* compared to *P. monodon* was mostly lost when the ratio of *L. vannamei* to *P. monodon* was 1:2 or 1:3, indicating that the competitive risks of *L. vannamei* escapes may be density-dependent (Chanavich et al., 2016). In addition, when paired with a common and widespread native crab, *Charybdis affinis*, in food competition contests, not only did the crab win every time, but it also occasionally caught and consumed the shrimp. This suggests that the crab may potentially control escapes and any possible established populations of *L. vannamei* by preying on them (Chanavich et al., 2016). Overall, it is likely that *L. vannamei* is able to survive in Indonesia waterways, given its wide range of tolerance to environmental conditions (e.g., salinity, pH, and temperature) and its ability to find and consume food in the wild in environments (Chanavich et al., 2016) (Panutrakul et al., 2010) (Senanan et al., 2010) (Puspasari and Suryandari, 2007). Regarding reproduction, although Senanan et al. (2010) found evidence of gonadal development in captured escapees (in Thailand), they also stated that it is “premature to conclude that the persistence of *L. vannamei* [in Thailand] is because of natural reproduction.”

A study by Puspasari and Suryandari (2007) examined the catch of nearshore shrimp and prawn fishers in Pangpang Bay, Banyuwangi, in July and October 2005. While the study found evidence of escaped *L. vannamei*, a species only legally farmed for the previous four years, its impact remains uncertain. *L. vannamei* formed a significant portion of the catch (5.4% in July, 7.63% in October), with high catch probabilities (40% in July and 53% in October) in certain gear types. But the overall catch abundance was low, and *L. vannamei* was primarily concentrated near the shoreline. This suggests limited dispersal into the bay, potentially minimizing the impact on native species. Nevertheless, the study’s temporal and spatial limitations prevent definitive conclusions about *L. vannamei*’s ecological effects across Indonesia. Analyzed together, this research is inconclusive regarding the true impact of escapees in the wild, and even if, to date, there is no indication of established populations, the consequences of the massive translocation of this species remain uncertain (Fernández de Alaiza García Madrigal et al., 2018).

Overall, a review of literature surrounding this topic revealed that there is no evidence of nonnative *L. vannamei* establishing viable populations anywhere in the world, and it is concluded that *L. vannamei* is likely to be present in the wild in Indonesia though not established, and highly unlikely to establish viable populations. Thus, the final score for Factor 6.2—Competitive and Genetic Interactions is 6 out of 10.

Conclusions and Final Score

For *L. vannamei* on intensive and semi-intensive farms, the escape risk that is associated with flooding (i.e., farm location) and the daily exchange rate (3–10%) is considered to be slightly lower than that for extensive farms, but is still high, and the score for Factor 6.1—Escape Risk is 3 out of 10. The escape risk of *L. vannamei* on extensive production systems is considered to be high, because they rely on tidal water exchanges and must be located in areas that are considered at high risk of flooding. As a result, Factor 6.1—Escape Risk scores 0 out of 10 for extensive systems.

A review of literature surrounding competitive and genetic interactions of escape farmed shrimp with wild species revealed that there is no evidence of nonnative *L. vannamei* establishing viable populations anywhere in the world, and it is concluded that, although *L. vannamei* is likely to be present in the wild in Indonesia, it is not considered to be established and is highly unlikely to establish viable populations. Thus, the score for Factor 6.2—Competitive and Genetic Interactions for *L. vannamei* is 6 out of 10. Combined, the final score for Criterion 6—Escapes for *L. vannamei* intensive and semi-intensive production systems is 4 out of 10. With a higher risk of escape, *L. vannamei* grown in extensive systems has a final Criterion 6—Escapes score of 3 out of 10.

Because *P. monodon* on farms originates from wild-caught broodstock, in the event of an escape, it is unlikely to present significant competitive or genetic risks to wild populations, given its native status and high genetic similarity to wild conspecifics. The score for Factor 6.2—Competitive and Genetic Interactions is 8 out of 10. Combined, the score for Criterion 6—Escapes for *P. monodon* in extensive production systems is 4 out of 10.

Criterion 7: Disease—Pathogen and Parasite Interactions

Impact, unit of sustainability and principle

- Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same water body
- Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.
- Principle: preventing population-level impacts to wild species through the amplification and retransmission, or increased virulence of pathogens or parasites.

Criterion 7 Summary: *L. vannamei* and *P. monodon*

Risk-based assessment

Pathogen and parasite parameters	Score	Critical?
Intensive systems: C7 Disease Score (0–10)	4	No
Semi-intensive systems: C7 Disease Score (0–10)	4	No
Extensive systems: C7 Disease Score (0–10)	6	No

Brief Summary

Data describing disease severity and frequency by species and or production system are limited (so the risk-based assessment is used), but the general literature indicates that shrimp farming in Indonesia is significantly affected by disease. For example, in 2018, it was estimated that the combined economic losses from shrimp diseases in Indonesia were about USD295 million (which was 74% of Indonesia's total aquaculture economic loss from disease in all farmed species). In 2020, the average annual industry mortality rate was 50%, and more recent data indicate a high variability in survival/mortality rates across production systems, seasons, and cycles (for which disease is one of many factors). A recent study reported that nearly half of all farms sampled (n = 120) experienced at least one disease issue per cycle, with the most frequent disease occurrences being AHPND ≈25%, EHP ≈5%, and WSD ≈11%, which can drastically reduce survival rates to potentially less than 10% in the worst cases.

Regulations and government agencies are focused on prevention, control, industry guidelines, and coordination among farms at the area level and at the farm level, to limit the spread of disease. This has resulted in monitoring, surveillance, testing, and government-led trainings on biosecurity (e.g., identification of disease symptoms, detection, control of pathogens, best management practices [BMPs], disease eradication, and disinfection). This indicates that there are some biosecurity measures and/or protocols in place, but there are apparent limitations in their effectiveness, due to the severity of disease-related issues seen on farms.

Evidence of disease transmission from farms to wild species is limited. Further research is needed because the risk of impacts to wild populations (compared to those in farms) from pathogens commonly found in shrimp farms continues to be uncertain. The variable host ranges of many pathogens mean that there is no robust reason to distinguish the two farmed shrimp species here regarding their risk of disease transmission to wild species.

Therefore, the score for Criterion 7—Disease is a combination of conditions, with scores differing by production system. Without further details readily available, it is assumed that semi-intensive and intensive production systems bear the burden of the noted high disease-related or pathogen-related mortalities that hamper the industry. This is due to the higher intensities (e.g., feed use and stocking density) of these systems and that the majority of production stems from semi-intensive and intensive production systems. Because there are government-led regulations, certifications, and interventions, there appears to be some level of biosecurity measures in place across the industry. Yet all production systems are still open to the introduction of pathogens and parasites and open to the discharge of pathogens, especially considering the average daily exchange rate of > 3% of untreated water. This results in a score of 4 out of 10 for Criterion 7—Disease for intensive and semi-intensive production systems.

Extensive production systems are associated with production practices that do not increase the likelihood of pathogen amplification compared to natural populations (there is no feed applied, and the stocking density is low: less than 10 post-larvae per m^2) (score of 8). The reportedly low survival rates for *L. vannamei* and *P. monodon* grown extensively (20–40%) are the result of high predation within these systems and the limited availability of feed/increased competition for resources—not primarily the result of disease. Because these systems are also within the industry-wide biosecurity governance and do not treat their discharge (score of 4), an intermediate score is warranted and results in a score of a 6 out of 10 for Criterion 7—Disease for extensive production systems.

Justification of Rating

On-Farm Disease

Viral and bacterial diseases and the associated economic impacts have fundamentally shaped the global shrimp farming industry (for a review of viral diseases, see Lee et al., 2022). Anecdotally, according to UNIDO's report (GQSP, 2023), and personal communication (Faturakhmat, 2023), disease is the biggest issue facing shrimp farmers in Indonesia. To indicate the severity of the issue (and in the absence of more detailed farm-level disease data that are representative across the industry), it is helpful to examine the economic impact of disease on Indonesian shrimp farming. For example, in 2018, the combined economic losses from disease in the aquaculture sector of Indonesia (all species) was about USD400 million (Evan Y., and Putri, N., 2021, citing Lusiastuti et al., 2020), while shrimp farming (*L. vannamei* and *P. monodon*) lost about USD295 million, or 74% of the annual aquaculture total.[113] The most significant diseases (from an economic perspective) for both *P. monodon* and *L. vannamei* were identified by the Directorate General of Aquaculture (DGA) monitoring and surveillance program, and are listed here with the approximate annual costs (Evan Y., and Putri, N., 2021 and Lusiastuti et al., 2020—see footnote for analysis method):

- White spot syndrome virus (WSSV) with a total loss estimated loss annually of USD189 million
- Infectious myonecrosis virus (IMNV) with a total loss of USD94 million
- Vibriosis (caused by bacteria of the *Vibrio* genus) with a loss of USD7.5 million
- Other with a loss of USD3 million

---

[113] Since Evans et al. (2021) cite Lusiastuti et al. (2020) as the data source for aquaculture losses in 2018, the shrimp value was calculated using the Lusiastuti et al. (2020) data, where the proportion of shrimp farm disease losses over the total losses (rupiah 3,900,000/rupiah 5,272,500 = ≈74%) was multiplied by the Evans et al. (2021) value total of USD400 million. The corresponding value for each disease was analyzed using the same method.

Although not reported by the DGA, the economic impact of infectious hypodermal and haemotopoietic necrosis virus (IHHNV) was also reported to be significant in 2018 (Evan Y., and Putri, N., 2021).

As for spatial data to describe disease frequency and type, there are limited publicly available data about Indonesia, despite the coordination and existence of several international disease-monitoring organizations. The World Organization for Animal Health (WOAH) monitors disease outbreaks through its WAHIS data portal.[114] The WAHIS database compiles disease reports by countries, both WOAH members and nonmembers, and includes information on listed animal diseases, emerging threats, and zoonoses. After verification, these data are publicly accessible through the WAHIS platform. For Indonesia, the only data period available in the database is 2016–19, but in these years there are confirmed reports of IMV, TSV, WSSV, and IHHNV across various provinces (n = 12) (Figure 7). This indicates that disease sampling has been conducted, but the reason for the lack of data after 2019 is not specified (e.g., data may not have been reported, or sampling may have ceased).

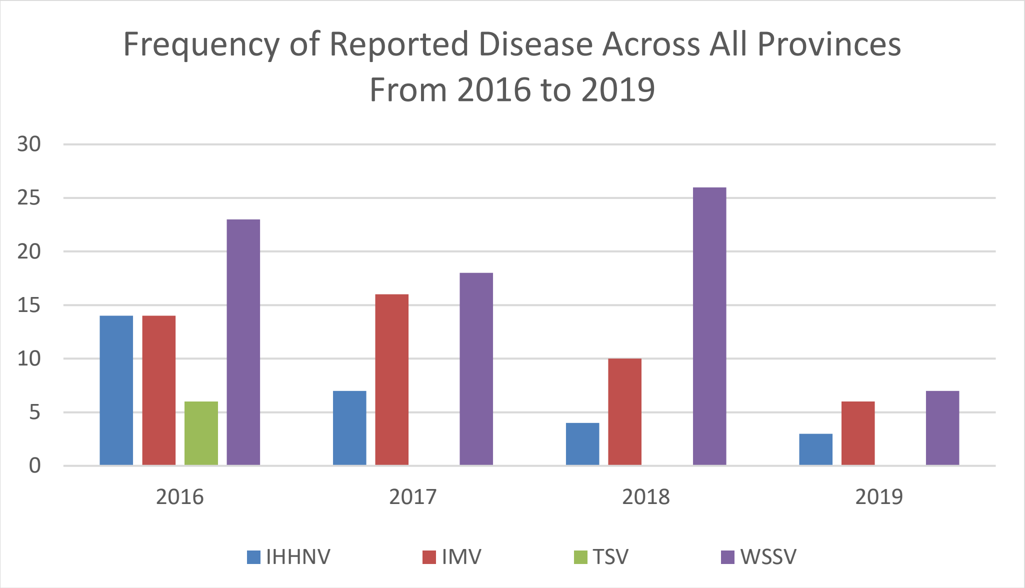

Figure 7: Frequency of reported disease in Indonesia across all provinces from 2016 to 2019. Source: World Organization for Animal Health, database accessed July, 2024.

Yet diseases of shrimp farming continue to evolve, and with the relatively rapid emergence and spread of novel pathogens, this challenge continues. For example, while the management of some diseases may improve with new strategies, farmers throughout Indonesia (and other countries) are most recently faced with increasing disease challenges due to white feces disease (WFD; and the associated microsporidian *Enterocytozoon hepatopenaei* [EHP] infections) and acute hepatopancreatic necrosis disease (AHPND; associated with *Vibrio parahaemolyticus* bacteria and commonly referred to as early mortality syndrome or EMS) (Tan, Muhtadi, H. et al., 2020)[115] (Desrina, D. et al., 2020). Although comprehensive data describing the impact of WFD, EHP, and AHPND are not readily available across the

---

[114] https://wahis.woah.org/#/dashboards/qd-dashboard

[115] The Aquaculture Roundtable Series (TARS) Leading Conversations Webinar (Shrimp Aquaculture: Managing AHPND, EHP and WFS), which featured Haris Muhtadi describing Indonesian shrimp aquaculture access on YouTube: https://www.youtube.com/watch?v=MO26eCe40O4.

industry, the severity of these diseases in Indonesia is considered "serious" and "increasing from area to area" as described by Muhtadi on the webinar in 2020.

As reflected by the annual economic losses detailed here, a recent article published on the Fish Site[116] suggests that the survival rate of farmed shrimp in Indonesia may be decreasing because of the evolving pressures of bacterial diseases such as EMS/AHPND and WFS. Since the spread of EMS in 2019, a farmer in Central Java describes the change in survival rate from 70% to 80% in 2019 to 30% at present after EMS outbreaks. The timeline of emerging diseases further underlines the ever-evolving challenges of disease development in shrimp farming; for example, in 2018, WSSV was the most pressing disease; in 2020, it was WFS/EHP; and in 2023, there appears to be an increase in EMS/AHPND.[117]

More recently, Muhtadi, H. (2020) estimated that the average annual industry mortality rate was 50% in 2020. Personal communications for this assessment from industry stakeholders reported current survival rates by production systems and species as follows (pers comm, Susanto, 2023) (pers comm, Widigo, Wibowo, 2023):

- *L. vannamei* intensive: 70–80%
- *L. vannamei* semi-intensive: 60–75%
- *L. vannamei* traditional: 30–40%
- *P. monodon* traditional: 20–30%

It is clear that there is substantial variation in these reported survival rates. Survival/mortality rates will be affected by several factors, of which disease (as discussed further) is of variable importance. For example, JALA tech reports[118] disease and survival rate data at a more granular level due to their unique data-centric business model. According to JALA, April, May, and September have the highest survival rates, which can reach 80% (JALA shrimp outlook 2023). Seasonal changes, such as rainy seasons (November to March), can influence disease outbreaks (pers comm, Faturakhmat, 2023), leading to declining survival rates (Figure 8).

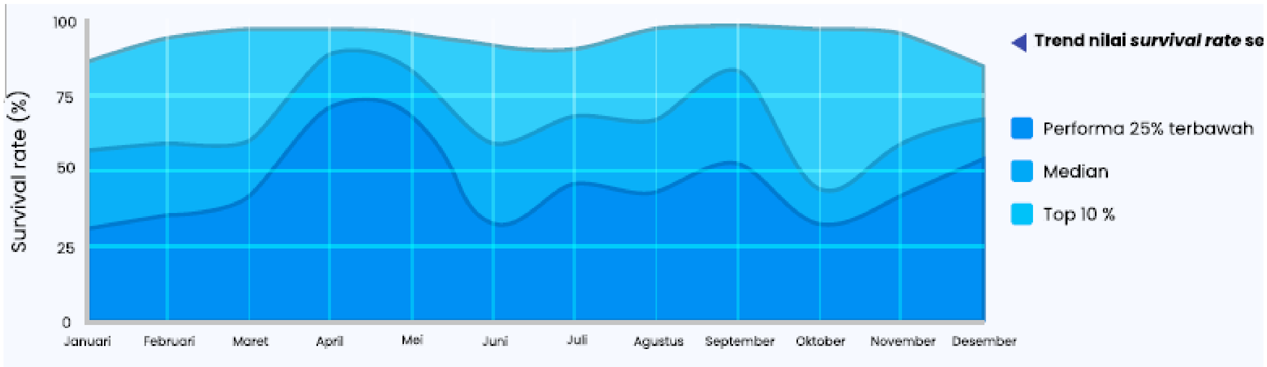

Figure 8: Survival rates of farms by month for one year. Source: JALA Shrimp Outlook, 2023. Translation of legend—Performa 25% terbowah: Bottom 25% performance; Median: statistical median; Top 10%: Top 10% performance.

---

[116] How shrimp farmers in Indonesia are navigating current challenges, Unies Ananda Raja, February 20, 2023. https://thefishsite.com/articles/how-shrimp-farmers-in-indonesia-are-navigating-current-challenges

[117] The Aquaculture Roundtable Series (TARS) Leading Conversations Webinar (Shrimp Aquaculture: Managing AHPND, EHP and WFS) https://www.youtube.com/watch?v=MO26eCe40O4.

[118] https://jala.tech/outlook/2023

Further, in an annual report by JALA (Shrimp Outlook, 2023), which analyzed 120 separate ponds for a total of 265 farming cycles over the course of 3 years for disease occurrence, disease was found to be a significant issue for farmers. Of the 265 samples, nearly 50% of shrimp cultivation cycles reported disease issues, with 3.7% having co-infections (i.e., multiple pathogens) (Figure 9). AHPND was found to be the most common pathogen, reported in 24.7% of ponds sampled.

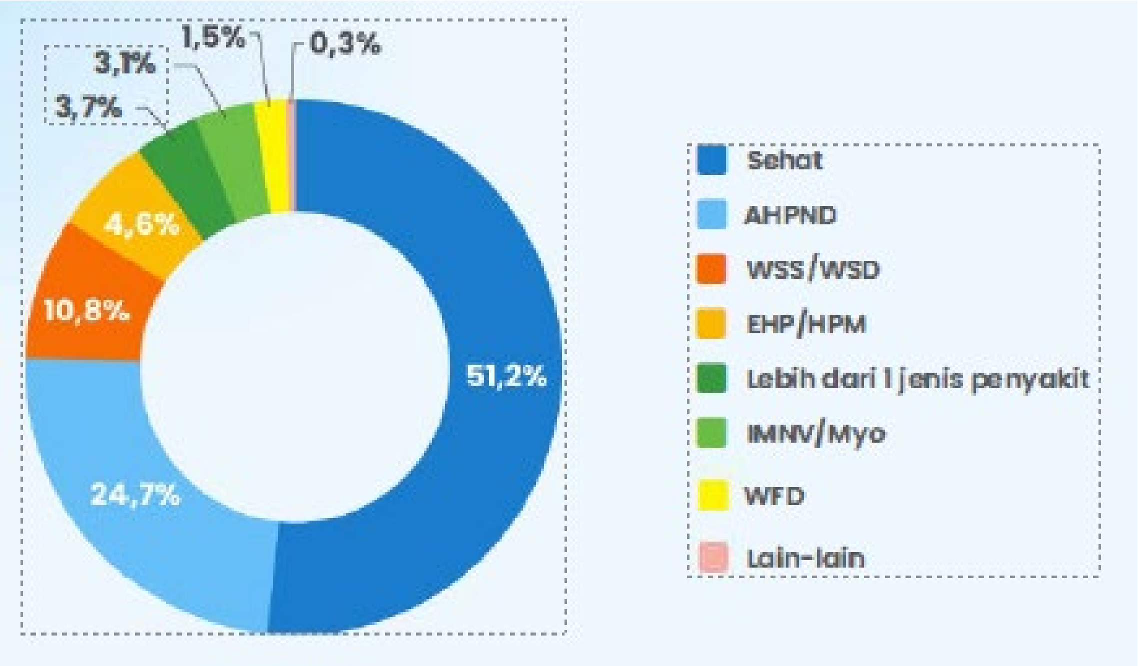

Figure 9: Presence of diseases over three years. Source: JALA Shrimp Outlook, 2023. Translation of legend—Sehat: healthy; AHPND: acute hepatopancreatic necrosis disease; WSS/WSD: white spot syndrome/white spot disease; EHP/HPM: *Enterocytozoon hepatopenaei*/hepatopancreatic microsporidiosis; Lebih dari 1 jenis penyakit: more than one disease; IMNV/Myo: infectious myonecrosis; WFD: white feces disease, Lain-lain: other.

The resulting impact of disease presence on the survival rates of these ponds was further assessed by JALA (Figure 10). According to the results, not all farms were affected similarly; rather, there is a wide distribution of potential impacts (i.e., Bottom 10%, Middle or Average, and the Top 10%). For example, the farms most affected by AHPND resulted in a survival rate of ≈8%, while the average survival rates (of affected farms) were ≈23%. For the top 10% of farms affected by AHPND, survival still exceeded 60%. Other diseases that were both significantly observed and with low survival rates are EHP/HPM and WSS/WSD. For both, not all the survival rates were reported in text, but according to Figure 10, the lowest survival rates appear to be ≈15% and ≈10%, and the averages were 42% and ≈38%, respectively.

Although the JALA data are somewhat limited in how much they represent the industry, they still help define the potential severity of disease challenges for farmers. Disease prevalence appears to be seasonal (with high survival rates in April, May, and September) and half of all farms experienced at least one disease issue per cycle, with the most frequent disease occurrences being AHPND ≈25%, EHP ≈5%, and WSD ≈11%, which can drastically reduce survival rates, potentially to less than 10% in some farms.

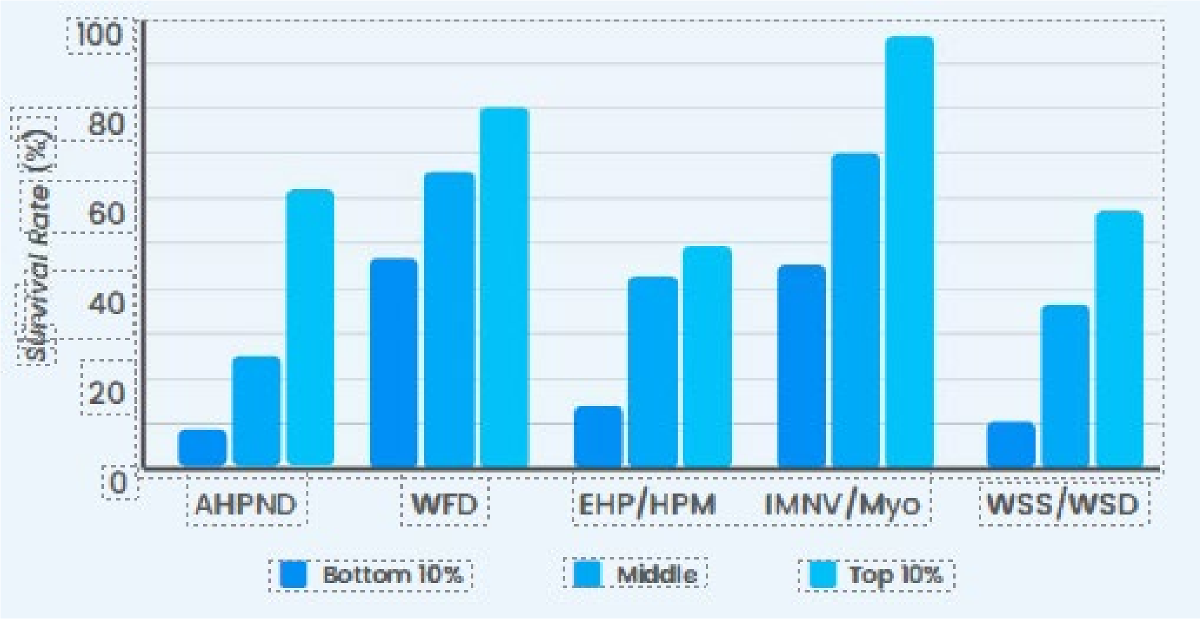

Figure 10: Survival rates of different diseases. Source: JALA Shrimp Outlook, 2023.[119]

Data provided by Central Proteina Prima Company Feedmill (pers comm, Budi, 2025) show a general decline in the percentage of farms testing positive for viral diseases (e.g., IMNV, WSSV) and bacterial diseases (e.g., EHP, WFD, vibriosis) from 2015 to March 2025, along with a low prevalence (i.e., < 20%) of diseases on farms. It is not clear how representative these data are for the shrimp farming industry, because key descriptions of the dataset were not made available (number of farms sampled per year, productions system types, location, etc.), but is interesting to note.

Information on disease prevalence between species and/or production systems was not readily available beyond the survival rates previously mentioned (see also the following section, *Differences across species and production systems*, for a look at attributes and transmission risk). There is limited insight from the World Organization for Animal Health's World Animal Health Information System (WAHIS) portal[120] (see Figure 8), and there also does not appear to be a quarterly report of aquatic animal health for Indonesia, despite it being a member of the Network of Aquaculture Centres in Asia-Pacific (NACA).[121] Nevertheless, because shrimp production in Indonesia is largely of *L. vannamei*, the resulting disease statistics discussed (survival rate, economic loss, prevalence) are likely attributes of *L. vannamei* production. Similarly, it must be noted that some of the important pathogens previously listed (specifically IMNV and IHHNV) primarily affect *L. vannamei*; for example, Flegel et al. (2009) describe IMNV as an *L. vannamei* disease and note that IHHNV is harmless to *P. monodon.* Yet, though data are limited, disease challenges and the potential risk to the surrounding environment may be significant with *P. monodon* production as well.

The main diseases affecting *P. monodon* are described, but further insight, such as prevalence (particularly in the extensive production systems assessed here) was not available. Diseases for *P.*

---

[119] https://jala.tech/outlook/2023

[120] Dashboard search for Indonesia aquatic animal disease incidence

[121] https://enaca.org/?id=8&title=quarterly-aquatic-animal-disease-report

monodon are reportedly: white feces disease (WFD; uncertain etiology), white spot disease (WSD) caused by white spot syndrome virus (WSSV), infectious hypodermal and hematopoietic necrosis (IHHN, caused by the eponymous virus, IHHNV; however, according to Flegel et al. (2009), IHHNV does not appear to cause disease with *P. monodon*), and monodon baculovirus (MBV) (pers comm, Anonymous, 2021). One study, Febri et al. (2022), reports low *P. monodon* production in Aceh from many causes, including viral and bacterial diseases (but no further details). Disease challenges with the culture of *P. monodon* in Indonesia have long hampered the industry, resulting in the mass industry switch to *L. vannamei* starting in 2002 (Flegel, 2009, citing Wyban, 2007a,b). As Flegel (2009) summarizes, the PLs from wild *P. monodon* broodstock "… were infected with WSSV. The broodstock transmitted the WSSV (along with other viruses) to their offspring. Thus, post larvae used to stock cultivation ponds were often the source of continuing WSSV disease (WSD) outbreaks." This may be an ongoing issue, as highlighted by Anshary et al. (2017), where viral infections continue to affect the hatchery program, starting with the broodstock, where viruses may be passed to their progeny.

For the sake of brevity, the specific bacterial or viral pathogen backgrounds are not detailed here because they are readily available elsewhere; for example, Arulmoorthy et al. (2020) [122] and Lee et al. (2022)[123] provide a comprehensive review of viral diseases in cultured shrimp, and Evan Y. et al. (2021) also provide a helpful review of each significant disease for Indonesia shrimp in 2018. The focus instead is on the sources and amplification of pathogens in farms, biosecurity/mitigation, and the transmission dynamics of the farming systems regarding the risk to wild shrimp.

Disease Management

Mitigation strategies of disease management include area-level and farm-level governance and management; however, the cumulative uptake and implementation has not been overly effective (as evidenced by the high disease-related mortality rates described previously). Collectively, disease management strategy, as discussed here, may be defined at an industry level and at an individual farm as biosecurity.[124] There is a need for more literature documenting biosecurity assessments and management practices of Indonesian shrimp farming (Delphino, M. et al., 2022), but what is available is detailed as follows.

Governance of Disease Management

In an attempt to limit the spread of disease, regulations and government agencies are focused on prevention, control, standard operating procedures (SOP), and coordination among farms at the area level and at the farm level. To reduce the spread of disease at the area level, task forces have been created; for example, due to the severity of AHPND impacts on global shrimp production, the Indonesian government created a task force that comprised government representatives, academics, and "stakeholders" focused on the prevention of AHPND (Evan Y., and Putri, N., 2021). A similar coordinated approach for aquaculture diseases more broadly (i.e., including fish) has also been developed: the Task Force Institution in Emergency Response of Fish Disease (Figure 11) (Evan Y., and Putri, N., 2021). The latter demonstrates a framework for coordination between stakeholder groups in the event of a disease outbreak, where government intervention—MMAF, DGA, and Fish Quarantine Agency—may help create

---

[122] Viral diseases are the major problem for the shrimp aqua farmers, and cause severe economic loss globally (Arulmoorthy et al., 2020).

[123] Viral Shrimp Diseases Listed by the OIE: A Review (Lee et al., 2022).

[124] Biosecurity is defined as "… those procedures, at the farm and area levels, used to reduce the probability that animals will contract, carry, and spread infectious agents and other non-desirable health conditions" (Delphino, M. et al., 2022 citing Lotz, 1997) (Pruder, 2004).

quarantine zones (Evan Y., and Putri, N., 2021) (DKP 2019). In addition, the task force "investigates the cause of mortality, provides guidance on the implementation of standard operating procedures for massive mortalities, and assists in key decisions regarding disease treatment procedures" (Southeast Asian State of Fisheries and Aquaculture, 2022). All disease outbreaks must be reported, and the Guidelines to Quarantine Fish for Aquaculture Producers help determine the level of risk of a particular disease (Sustainable Fisheries Partnership, 2021 citing MMAF 2014) (MMAF 2019b).

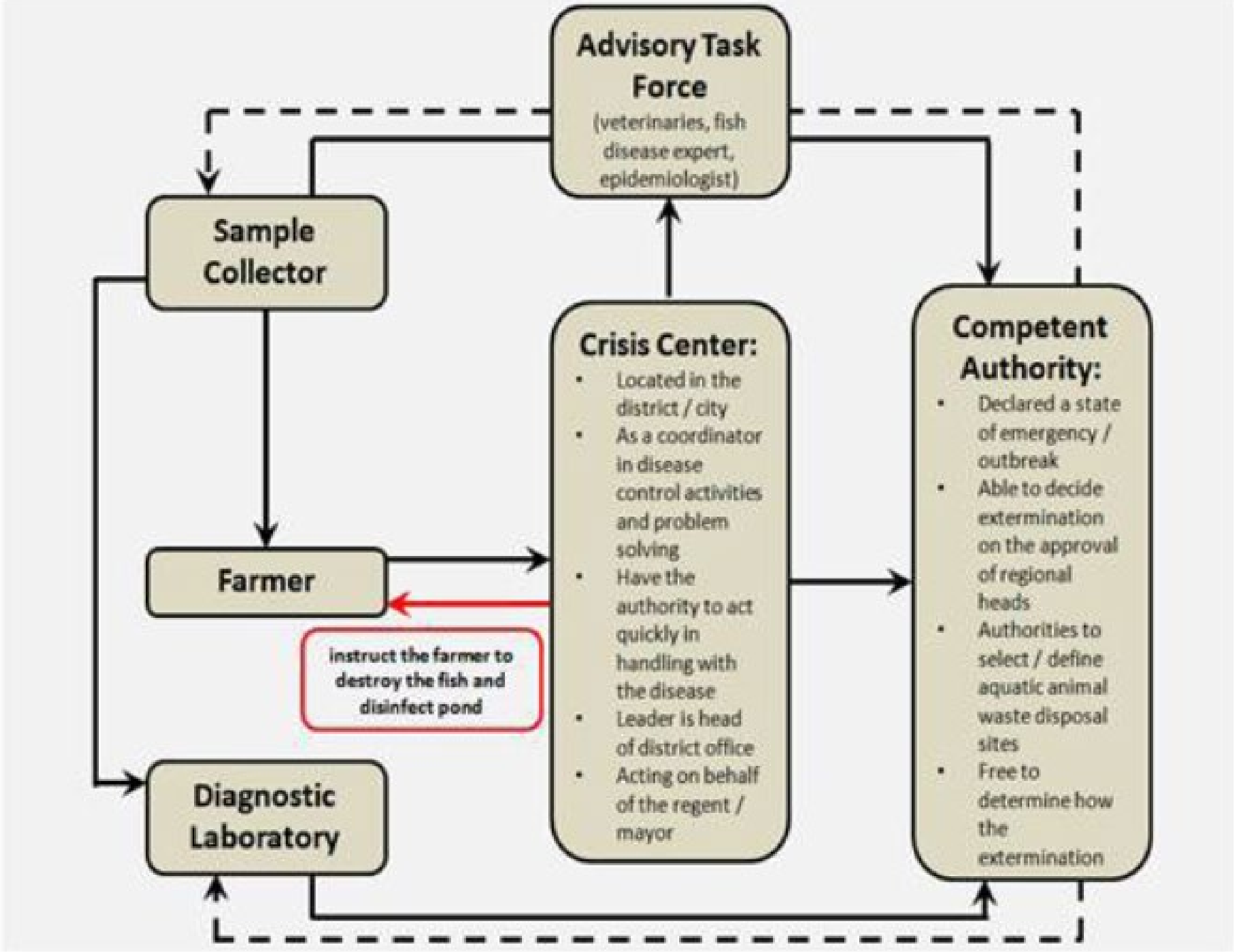

Figure 11: The Task Force Institution in Emergency Response of Fish Disease (Evan Y., and Putri, N., 2021).

At the farm level, Regulation No. 75-2016 "General guidelines for rearing *monodon* and *vannamei* shrimps," farm biosecurity, and BMPs were developed collaboratively by FAO & MMAF (2015). These guidelines include fish disease controls such as isolating sick shrimp, the appropriate disposal of dead shrimp due to disease, the use of pathogen-free (SPF) post-larvae, reporting cases if outbreaks occur, the sterilization of tools, fencing, bird and crab deterrents, and control of workers' movement. In addition, SOPs for hatcheries and grow-out farms and the taking of samples of shrimp have been developed and shared with Indonesian shrimp farmers.[125]

Another important component of disease management is efficient disease detection and monitoring. To help identify pathogens, there are 140 aquatic animal disease laboratories throughout Indonesia, operated by a mix of national and local agencies (Southeast Asian State of Fisheries and Aquaculture, 2022).

Monitoring for disease is routinely conducted by the government, although the process is unclear. According to GQSP UNIDO (pers comm, 2021), government officials (i.e., the Environmental Agency, the district/city Marine Affairs Agency) take samples every 6 months from farms for lab testing, with an increasing frequency during a disease outbreak. The monitoring and surveillance program consists of 91 laboratories across Indonesia operated by the Ministry of Marine Affairs and Fisheries (Evan Y., and Putri, N., 2021). In addition to disease detection, the laboratories help with water quality testing and fish disease prevention recommendations (Evan Y., and Putri, N., 2021). There do not appear to be any readily available public data from these detection and monitoring programs currently, but annual reports did exist at one point on the MMAF website (pers comm, Bulcock, 2024). The sampling locations are specific sampling points, but further insight was not readily available.

It appears that, if there are confirmed disease issues (i.e., positive lab results or farmer identification), farmers must report them to the Fish Quarantine Agency and local government and submit all records of disease observations (pers comm, MMAF, Faturakhmat, 2021). Depending on the type of disease and severity, the Task Force Institute has set protocols (as described previously), and for less severe cases (the threshold is unclear), farmers focus on containment and treatment.

Ultimately, the ability to mitigate the proliferation of disease occurrence at an area level requires the uptake and effective implementation of biosecurity protocols (i.e., uptake of BMPs, regulatory effectiveness, supply of SPF PLs, water treatment, and disease monitoring) at the farm level. But the efficacy and the effectiveness of the region- and area-based biosecurity programs in Indonesia (i.e., the Task Force Institution in Emergency Response of Fish Disease) do not appear robust, due to the introduction and documented outbreaks of EMS/AHPND in some farms. Improvement is needed to help reduce the risk of disease introductions at the farm level.

Farm-Level Disease Management

At the farm level, mandatory disease management guidance must be followed in accordance with IndoGAP CBIB (BSN, 2022). But the implementation of IndoGAP CBIB appears new and does not yet appear to have been widely adopted, so what is known about general farm practices is also reported.

IndoGAP CBIB and Industry Guidance

Biosecurity principles required for CBIB certification include general farm maintenance and health management (BSN, 2022). Farm maintenance requirements are few, and include disinfecting equipment and disposal of waste in receptacles. Health management includes guidance and principles to be achieved; for example, manage the farm to maximize survival rates and monitor shrimp health routines by visual observations and/or testing in a laboratory. If shrimp have a disease issue, shrimp should be

---

[125] YSAI AIP Seminar Series Management of Vannamei Shrimp Culture in Facing AHPND Disease. https://sustainaquaindonesia.org/en/2022/02/21/ysai-aip-seminar-series-management-of-vannamei-shrimp-culture-in-facing-ahpnd-disease/

isolated and equipment should be cleaned; if the shrimp health does not improve, shrimp should be burned and the pond bottom and water should be disinfected. In addition, limiting disease entry points is emphasized by limiting access to the farm, disinfecting clothing, and using pond netting to protect the pond from pests or predators. There is also an emphasis on training employees on the importance of these biosecurity principles.

Other guidance from GQSP (2021, 2023) and SOP from MMAF (2021) echoes implementing the principles of IndoGAP CBIB. In addition, there is guidance to source only SPF fry and to source from hatcheries where post-larvae can be inspected through visual and/or PCR tests before purchase. Also, farms should only source from hatcheries that are certified to IndoGAP Good Fish Hatchery Practices (CPIB).

Common Farm Practices

Besides IndoGAP CBIB requirements and other industry guidelines, general farm practices are commonly implemented to help mitigate disease. Monitoring for diseases is typically through daily observations of shrimp behavior by farm operators (pers comm, FUI, GQSP UNIDO, 2021). Records of these observations must also be maintained by the farmer (pers comm, MMAF, 2021), although the structure and the data requirements are unclear. If there are disease issues suspected, samples may be delivered to in-house veterinary labs (≈10% of the industry have this option, and are the attributes of medium and large enterprises), government labs, or private labs (e.g., JALA tech, Feed Mills) (pers comm, Faturkahmat, CPP, GQSP UNIDO, 2021).

The design and operations of farms and ponds are key areas for disease management and mitigation. Pathogens can enter farms in influent water (during pond filling or water exchanges) or with post-larvae/juveniles stocked into the ponds, in addition to many other potential routes including via workers or equipment, wildlife, or feed, so it is important to develop on-farm biosecurity protocols.

Regarding post-larvae/juveniles for stocking, according to Emerenciano et al. (2022), the use of specific pathogen-free (SPF) broodstock has provided the central pillar to mitigate disease risk for those pathogens that posed the greatest disease risk to shrimp farming. And, the use of SPF PLs/broodstock is a common disease mitigation strategy of *L. vannamei* farms/hatcheries in Indonesia (pers comm, Faturakhmat, FUI, 2021) (Amelia, F. et al., 2021). Indeed, the initial driver for domestication was the industry's need for commercial broodstock that was free of certain pathogens commonly found in the wild sources. Thus, specific disease risks could be mitigated, if not wholly removed, by breeding companies developing SPF domesticated breeding lines maintained in highly biosecure facilities. Nevertheless, while SPF lines provide an ideal starting health status for farming, these stocks are still vulnerable to pathogen infection once in the ponds, and Emerenciano et al. (2022) consider that it is increasingly challenging to maintain a pathogen-free status through the production tiers from broodstock through hatcheries and the grow-out cycle in ponds. As stated, the vertical transmission of WSSV from wild *P. monodon* broodstock to their offspring had a major impact on the proliferation of WSSV across the industry, resulting in the collapse and shift to *L. vannamei* around 2002. Therefore, the testing of PLs before stocking is an important component to limit the spread of disease from hatchery to grow-out ponds for *P. monodon*.

The screening of seed before stocking for grow-out appears common. In a webinar in early 2022, Haris Muhtadi (Chairman of Shrimp Club Indonesia, SCI) stated that PCR tests are mandatory for all PLs before selling fry to the farmers in Indonesia.[126] Details were not readily available to confirm, but this would certainly be a helpful step to help ensure quality seed availability for farmers before stocking. A survey by Delphino, M. et al. (2022) of micro-small, small, medium- and large-scale farms in Java, Lampung, and Banyuwangi found that 60–65% of farmers assessed the quality of PL before stocking. Test evaluations and frequency include stress test (66%), gut filling screening (10%), *Vibrio* bacterial culture (9%), and hepatopancreas screening (6%). But PL quality is frequently cited as a challenge for farmers, primarily *P. monodon* (pers comm, Desyana, 2023) (FAO and MMAF, 2015) (Anshary, et al., 2017).

Also, treatment of pond bottoms between harvests, as well as the incoming and outgoing pond water, is an important control point for limiting disease proliferation at the farm and area level; hence, the importance of the Task Force Institution in Emergency Response of Fish Disease. Lime (i.e., calcium oxide, calcium carbonate, or dolomite lime) is often used to raise the pH of pond bottoms drying between crop cycles, to destroy disease-causing organisms (Boyd et al., 2018) (pers comm, CPP, MMAF, Faturakhmat, Pratiwi, 2021) (pers comm, Desyana, 2023). Disinfectants may also be applied to reservoirs (if they exist) and ponds before stocking. A list of chemicals commonly used was acquired through personal communication and includes saponin, crustacide (active compounds unknown), nuvet (active compounds unknown but notes a crustacide), potassium permanganate, chlorine, and copper sulphate. Their purposes are to disinfect water and soil that may contain disease-causing organisms, as well as serving as piscicides (Boyd et al., 2018) (Sivaramakrishnan, T., & Renganathan, R., 2013) (Yasir et al. 2021) (pers comm, CPP, GQSP UNIDO, Faturakhmat, Pratiwi, 2021). Probiotics are also applied before post-larvae are stocked, to help manage the microbiological management of the pond bottom, to promote beneficial phytoplankton growth and water quality, and to improve the shrimp larval immune system (see Criterion 2—Effluent). But the implementation of biosecurity controls such as pond bottom treatment, treating water before use, and stocking density may vary depending on the production system type (as discussed in the following section).

Intensive Systems

The stocking density of intensive *L. vannamei* production systems is high and estimated to be greater than 50–200 post larvae per m^2 (MMAF, 2021) (pers comm Budhi Wibowo, 2023, citing Indonesia Shrimp Forum, 2019) (Halim, D. 2016, citing Ministry of Maritime Affairs and Fisheries), and from a basic understanding of epidemiology, a greater intensity of production is commonly associated with a higher risk of disease (e.g., Schar et al., 2020). Nevertheless, intensive systems (due to their smaller volume and total area) have the option of greater control of incoming and outgoing water (compared to extensive and semi-intensive systems), because they may consist of reservoirs and settlement ponds and are more biosecure. For incoming water, if reservoirs are used, they typically store water for 12–48 hours (pers comm, MMAF, CPP, 2021) (Delphino, M. et al, 2022), which allows the opportunity to treat (i.e., disinfect) the water before its use, though data describing how commonly this is practiced are not readily available. For outgoing discharges, water is typically untreated for pathogens in Indonesia, and this may be a critical control point issue to improve farm biosecurity and dampen disease outbreaks. In Vietnam, pathogens in influent waters are commonly a circular challenge, and Khiem et al. (2022) consider that once a pond becomes infected, it is difficult to prevent the spread of the disease to nearby shrimp farming areas. For example, wastewater (plus sediment and sludge) from shrimp farms is often discarded directly into the same waterbody serving as source water for other farms, which can lead to severe and persistent disease outbreaks and economic losses to the farmers (Ngoc et al., 2021) (Nguyen et al., 2020) (Xuan et al., 2021). This pattern seems applicable to Indonesia as well. A survey by

---

[126] TARS Leading Conversations Webinar (Shrimp Aquaculture: Managing AHPND, EHP and WFS) access on YouTube: https://www.youtube.com/watch?v=MO26eCe40O4

Delphino, M. et al. (2022) of intensive *L. vannamei* farms in Banyuwangi (East Java) found that, when disease outbreaks occurred on a farm, they also simultaneously occurred on a neighboring farm nearly half the time (43.6%). The same survey showed that disease also seems common: "Farms also reported disease in the previous crop cycle (67.3%) and that disease was the reason for treating ponds (e.g., with feed, water/bath, or other methods) in the previous crop cycle (78.2%)." After a harvest, 97% of farmers dried ponds before starting a new crop cycle, and 99% used either chemical or nonchemical methods for pond preparation (Delphino, M. et al, 2022).

Semi-Intensive Systems

Semi-intensive systems utilize earthen pond bottoms or pond liners, though the percentage of either was not readily available in the literature. Information on the adoption of a reservoir and treating (i.e., disinfecting) water before use is not readily available, and the usage of sediment ponds is limited to ≈10% of all *L. vannamei* farms (Boyd et al. 2021a). Semi-intensive systems typically have a higher daily exchange rate of 5–10%, and ponds are typically drained at harvest; however, the fallowing/drying time between cycles is minimal. The survey by Delphino, M. et al. (2022) of small and micro-scale farms (likely semi-intensive and/or extensive farms) in Lampung and Java found that 75% of farmers did not dry ponds before starting a new crop cycle and, if they did, the duration was < 7 days. The stocking density of semi-intensive *L. vannamei* production systems is estimated to be 20–50 post-larvae per m^2 (Sari, I., 2015, citing Zainun et al. 2007).

Extensive Systems

Extensive shrimp farming attributes include no lining of pond bottoms and little control of incoming and outgoing water. Nevertheless, because of the low stocking densities, these farms typically do have the option to avoid water exchanges for some time if there is a known disease problem in the vicinity, and through a basic understanding of epidemiology, they may have a lower risk of disease outbreaks. Water input is reliant upon tidal fluctuation and a sluice gate, which controls the incoming water volume and water exchange (output). There is no water treatment (other than a screen to limit movements of potential pathogen carriers such as fish, crabs, or other shrimp) for either incoming or outgoing water exchanges. With intermittent water exchanges (using the highest tides each month), the average daily total water exchanges are relatively low, and estimated to be < 3% per day (pers comms Saenong, 2025). Given the survey findings by Delphino, M. et al. (2022), it does not appear that pond bottom preparation, drying, and/or fallowing is common for extensive systems, because the low-lying nature of the ponds makes it difficult to dry them thoroughly, and extensive farmers may not feel the need. The stocking density is quite low: estimated to be less than 10 post-larvae per m^2 (pers comm, Pratiwi, 2021). The survival rates reported (*L. vannamei*: 30–40%; *P. monodon*: 20–30%) for extensive systems are the lowest for all production systems, but the primary cause of the low survival rates is the high predation from within extensive ponds (i.e., finfish) (pers comm, Anonymous, 2023). These systems also have low inputs, such as fertilizers and feed, so the availability of resources, while competitive, resembles more natural conditions—thus, the low survival rates of post-larvae.

Impacts to Wild Shrimp

In contrast with the amount of information available regarding disease pathology on farms, there is limited research or evidence to indicate that shrimp farms in Indonesia are exerting a pathogen/disease pressure on wild populations of shrimp and other crustaceans, nor is there evidence to suggest that they are not. Bacteria and viruses are ubiquitous in seawater; for example, there are approximately 10 million viruses per milliliter of seawater (Bergh et al., 1989). Most of the relevant diseases are caused by the opportunistic microorganisms that are part of the microflora and fauna of the penaeid shrimp (Arulmoorthy et al., 2020), and pathogens such as white spot syndrome virus (WSSV) are endemic in most shrimp-producing countries, including Indonesia, with broad host ranges (Zwart et al., 2010) (Dhar et al, 2022). Studies on the detection of various pathogens in wild shrimp are often associated with the search for pathogen-free sources of wild *P. monodon* broodstocks, and demonstrate the common detection of various pathogens associated with diseases in shrimp farms; e.g., Anshary et al. (2017) in Indonesia, Orosco et al. (2017) in the Philippines, Hamano et al. (2017) in Thailand, Dutta et al. (2015) in India, and Arbon et al. (2022) in Australia. There is no implication in these studies of a concern for the wild shrimp populations due to the detection of these pathogens. Indeed, Chellapnadian et al. (2023) noted that, although more than 20 viruses have been found to infect both wild marine shrimp and farmed shrimps, the wild shrimp do not show any sort of symptom of disease, even with the presence of the pathogen. Taura syndrome virus (TSV) was previously an important pathogen for *L. vannamei* and was introduced into Asia in 1998 by the careless importation of shrimp stocks for aquaculture, but this virus has not been reported to cause problems with local crustacean species (Flegel et al., 2009). Further, because IMNV (noted previously as one of the most significant diseases regarding economic losses) primarily affects *L. vannamei* and there are no wild cohorts of this species in Asia (WOAH, 2021), there does not appear to be any substantial risk to native species in Indonesia from this pathogen.

The only demonstrated impact to wild shrimp is from the 1990s, when an IHHNV outbreak resulted in significant losses in both farms and wild fisheries for the blue shrimp, *P. stylirostris*, in Mexico (Lightner, 2011). As noted previously, shrimp farming has been plagued with several severe viral disease epidemics, and Lee et al. (2022) note that new viral diseases occur rapidly. Existing diseases can evolve into new types, so there is apparently an ever-present risk that pathogens evolving in shrimp farms could potentially be transmitted to wild shrimp. Nevertheless, it is also important to note that the increased sensitivity of advanced molecular techniques can cause difficulty in interpreting the biological significance of such detections in wild organisms. For example, detections of “new” (unknown or known but discovered in a different geographic location or fish host) potentially infectious agents can be misinterpreted because molecular detection is not proof of agent viability within or on host tissues (Meyers and Hickey, 2022). Further investigation is required regarding the agent’s ability to replicate and to provide evidence that the agent causes substantial risk of disease to exposed wild populations (Meyers and Hickey, 2022). Therefore, the risk of impacts to wild populations (compared to those in farms) from pathogens commonly found in shrimp farms continues to be uncertain.

Summary of Differences across Production Systems and Species

There are many aspects of the different production systems and their management that relate to their biosecurity and/or vulnerability to disease. A particular challenge is to understand the differences in the pathogen dynamics in the various shrimp farming systems (with highly variable shrimp stocking densities, water quality, and other stressors, etc.), which may increase the disease transmission risk, compared to the dynamics of the same pathogens in wild shrimp.

- Intensive farms typically use plastic pond liners and have the ability to clean and dry the pond substrates between cycles, and are perhaps more likely to use high-quality, SPF post-larvae than extensive farms. Yet the high stocking densities (50–200 post-larvae per m^2) of intensive farms are widely acknowledged to have a higher risk of pathogen amplification and clinical disease outbreaks than lower densities, as in extensive farms (e.g., Schar et al., 2020). Also, the average daily exchange rate is significant (> 3%; see Criterion 3—Effluent) and there is typically no treatment of pathogens from pond discharge water, effectively resulting in a production system open to the surrounding environments, with a limited understanding of typical biosecurity management measures. Thus, there is inevitably some concern for disease transmission risk from these systems.

- Semi-intensive farms typically have limited treatment of the pond bottom, and pond effluent is not treated to prevent the discharge of any potential pathogens. There may be sourcing of SPF shrimp and there is a lower stocking density (20–50 post-larvae per m^2) compared to intensive systems. Similar to intensive systems, there is a substantial average daily exchange rate (5–10%), and semi-intensive ponds drain to natural waterways (as opposed to on-farm reservoirs) at harvest. These systems are therefore considered open to the surrounding environments, with a limited understanding of typical biosecurity management measures resulting in some concern for disease transmission risk from these systems.
- Extensive farms generally are unable to dry the soil bottom between cycles, due to the siting of extensive farms within the tidal zone and the high water table (Boyd et al. 2021b). And, access to quality post-larvae is frequently cited as an issue for *P. monodon* (pers comm, Desyana, 2023) (FAO and MMAF, 2015). The average daily exchange rate is low (< 3% per day), and the stocking density is considered quite low (< 10 post larvae per m^2). This allows for more natural conditions with lower stress than more intensive systems, resulting in a lower risk of pathogen transmission from these systems. The low reported survival rates (20–40%) are considered to be due to high predation within these systems and the limited availability of feed/increased competition for resources—not primarily disease.

For the two species, differing disease characteristics and patterns of epidemics (along with the varying availabilities of SPF post-larvae) have been the defining aspects of the evolution of the shrimp farming industry in Indonesia and elsewhere. Although SPF lines of *L. vannamei* are available, other factors still control the risk of disease outbreaks on farms, regardless of the species. Although there are native *P. monodon* in Indonesia and no *L. vannamei*, the variable host ranges of many pathogens mean that there is no robust reason to distinguish the two species here regarding their risk of disease transmission to wild shrimp.

Conclusions and Final Score

The data describing the disease severity and frequency by species and/or production system are limited (so the risk-based assessment is used), but the general literature indicates that shrimp farming in Indonesia is significantly affected by disease. For example, in 2018, it was estimated that the combined economic losses from shrimp diseases in Indonesia was about USD295 million (which was 74% of Indonesia's total aquaculture economic loss from disease in all farmed species). In 2020, the average annual industry mortality rate was 50%, and more recent data indicate a high variability in survival/mortality rates across production systems, seasons, and cycles (for which disease is one of many factors). A recent study reported that nearly half of all farms sampled (n = 120) experienced at least one disease issue per cycle, with the most frequent disease occurrences being AHPND ≈25%, EHP ≈5%, and WSD ≈11%, which can drastically reduce survival rates to potentially less than 10% in the worst cases.

Regulations and government agencies are focused on prevention, control, industry guidelines, and coordination among farms at the area level and at the farm level, to limit the spread of disease. This has resulted in monitoring, surveillance, testing, and government-led trainings on biosecurity (e.g., identification of disease symptoms, detection, control of pathogens, BMPs, disease eradication, and disinfection). This indicates that there are some biosecurity measures and/or protocols in place, but there are apparent limitations in their effectiveness due to the severity of disease related issues seen on farms.

Evidence of disease transmission from farms to wild species is limited, and further research is needed because the risk of impacts to wild populations (compared to those in farms) from pathogens commonly found in shrimp farms continues to be uncertain. The variable host ranges of many pathogens mean that there is no robust reason to distinguish the two farmed shrimp species here regarding their risk of disease transmission to wild species.

Therefore, the score for Criterion 7—Disease is a combination of conditions, with scores differing by production system. Without further details readily available, it is assumed that semi-intensive and intensive production systems bear the burden of the noted high disease-related or pathogen-related mortalities that hamper the industry. These are the result of the higher intensities (e.g., feed use and stocking density) of these systems and because the majority of production stems from semi-intensive and intensive production systems. Because there are government-led regulations, certifications, and interventions, there appears to be some level of biosecurity measures in place across the industry, yet all production systems are still open to the introduction of pathogens and parasites and open to the discharge of pathogens, especially considering the average daily exchange rate of > 3% of untreated water. This results in a score of 4 out of 10 for Criterion 7—Disease for intensive and semi-intensive production systems.

Extensive production systems are associated with production practices that do not increase the likelihood of pathogen amplification compared to natural populations (there is no feed applied, and the stocking density is low: less than 10 post-larvae per m^2) (score of 8). The reportedly low survival rates for *L. vannamei* and *P. monodon* grown extensively (20–40%) are due to high predation within these systems and the limited availability of feed/increased competition for resources—not primarily disease. Because these systems are also within the industry-wide biosecurity governance and do not treat their discharge (score of 4), an intermediate score is warranted and results in a score of a 6 out of 10 for Criterion 7—Disease for extensive production systems.

Criterion 8X: Source of Stock—Independence from Wild Fisheries

Impact, unit of sustainability and principle

- Impact: the removal of fish from wild populations for on-growing to harvest size in farms
- Sustainability unit: wild fish populations
- Principle: using eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture.

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

Criterion 8X Summary: *L. vannamei*—all production systems

Source of stock parameters	Score
C8X Independence from unsustainable wild fisheries (0–10)	0
Critical?	NO

Criterion 8X Summary: *P. monodon*—extensive production systems

Source of stock parameters	Score
C8X Independence from unsustainable wild fisheries (0–10)	–10
Critical?	NO

Brief Summary

Nearly all black tiger prawn broodstock are sourced from the wild, and the status of the wild *P. monodon* stock is considered to be overexploited, so the score for *P. monodon* in Criterion 8X—Source of Stock is –10 out of –10. With no use of wild caught broodstock (or PL), the final score for Criterion 8X—Source of Stock for *L. vannamei* is a deduction of 0 out of –10.

Justification of Rating

This criterion assesses the use of wild juveniles (post-larvae, or PL, in the case of shrimp farming) or wild broodstock. Because the supply of PLs comes almost entirely from hatcheries as opposed to wild capture, this criterion assesses the source of broodstock from which hatchery PLs are produced. To avoid confusion with hatchery-raised PLs, broodstock here refers to either wild-caught (from capture fisheries) or domesticated (raised on farms or specialist broodstock units, as opposed to wild-caught[127]).

Total statistics regarding the overall industry such as size, location, and number of hatcheries were not readily available, but as a whole, the *L. vannamei* hatchery industry has grown by ≈15% from 2014 to

---

[127] Note that these broodstock may not truly be "domesticated" in terms of lengthy selective breeding for specific traits, but the term is still useful to distinguish from wild-caught sources.

2018 (Pongoh, I., et al., 2021) and broodstock are domesticated. Broodstock for *P. monodon* are sourced from the wild.

L. vannamei Broodstock
L. vannamei is a nonnative species in Indonesia, and aquaculture production relies entirely on domesticated breeding programs for broodstock. Indonesia imports 60–80% of the *L. vannamei* broodstock from Hawaii and Florida in the United States, with the remaining portion selected from private and government-led domestic broodstock ponds in Indonesia (pers comm, FUI, 2021) (Briggs et. al. 2005) (NALO 2006) (Ardjosoediro and Goetz 2007) (GAIN 2007) (Yi et al. 2009) (Anonymous 2015a) (Amelia, F. et al., 2021) (Shishehchian, 2011). Large-scale hatcheries capture ≈80% of the hatchery market share in Indonesia, with the remaining 20% from small hatchery enterprises (pers comm, FUI, CPP, 2021). In general, hatcheries are concentrated in West Java, East Java, Lampung, South Sulawesi, Bali, and the islands of Nussa Tenggara (pers comm, GQSP UNIDO, 2021), which correlates with the largest-producing shrimp farming islands. With no use of wild caught broodstock (or PL), the final score for Criterion 8X—Source of Stock for *L. vannamei* is a deduction of 0 out of –10.

P. monodon broodstock
According to the MMAF (pers comm, 2021) and Susanto & Wibowo (pers comm, 2024), 100% of *P. monodon* broodstock are sourced seasonally (when adults are ready to spawn) from the wild, with the main fishery located in Aceh Province (Sumatra). Fishers catch *P. monodon* using trammel nets, which are sized specifically for the *P. monodon* broodstock fishery off the shores of Indonesia—primarily along the coast of East Aceh in the Malacca Strait (WWF Indonesia, 2020) (pers comm, Faturakhmat, 2023). Other, more ecologically destructive gear are also used, such as bottom trawling (Tjahjo et al. 2019); although trawling has been recently re-banned in Indonesia,[128] it appears to still be in use to some degree[129] (Ramdhani, 2022). Once caught, the broodstock is held in holding tanks and follows quarantine procedures for trans-waterbody movement (see Criterion 10X). Eventually, the broodstock is delivered to hatcheries throughout Indonesia, notably Aceh, Lampung, West Java, East Java, Kalimantan, and South Sulawesi (pers comm, Pratiwi, MMAF, FUI, GQSP UNIDO, 2021) (Leadbitter, D. and Peet, C., 2020). Roughly 30% of the *P. monodon* hatchery market share in Indonesia is held by large-scale hatcheries, while 70% is small-scale hatcheries (pers comm, FUI, 2023). Although the main source for broodstock is in Aceh, other fishing areas like Papua have, reportedly, good mangroves and have the best broodstock supply. But because of the distance from hatcheries, this fishery is considered to supply a minority of broodstock (pers comm, Desyana, 2023). Given that the primary source of *P. monodon* broodstock is the wild, determining the sustainability of the wild *P. monodon* fishery is the focus of this section.

The Indonesian fisheries governance framework is primarily managed by the Ministry of Marine Affairs and Fisheries, with shared responsibilities among national, provincial, and local authorities (OECD 2013), including traditional structures like the Panglima Laot (pers comm, Susanto and Wibowo, 2024). The framework encompasses a comprehensive set of laws, regulations, and monitoring systems that cover aspects such as fishing permits, catch quotas, gear restrictions, and vessel monitoring (MMAF, 2023a) (MMAF, 2023b) (MMAF, 2013) that are aimed at promoting sustainable fisheries management, while a

---

[128] https://news.mongabay.com/2021/07/indonesia-reimposes-ban-on-destructive-seine-and-trawl-nets-in-its-waters/

[129] https://fisheryprogress.org/sites/default/files/indicators-documents/FisheryProgress_Three_Year_Audit_Report_Kotabaru%20shrimp%20final.pdf#overlay-context=node/7428/improvement

Presidential Task Force has been created to combat illegal fishing (OECD 2018). Although the framework is extensive, its effectiveness is challenged by issues such as jurisdictional overlaps, limited local government capacity, weak monitoring and enforcement, and persistent illegal fishing practices (Nurhidayah, 2010) (CCIF, 2013) (FAO, 2017) (Napitupulu et al., 2022) (CEA, 2018), thus highlighting areas for potential improvement in coordination, data quality, and the implementation of existing regulations.

As a result of these fishery governance challenges, the current stock status of the *Penaeid* shrimp fishery (including *P. monodon*) in the fishery management areas (WPP) around Aceh is considered overexploited (WPP 571 and WPP 572) (Napitupulu et al., 2022, citing KEPMEN-KP 19/2022). Further, according to Tjahjo et al. (2019), the "exploitation rate of tiger prawns is very high" off the coast of Aceh. The exploitation appears to be directly linked to the high demand for broodstock, with an increase of 38% per year in the number of fishers targeting the stock from 2010 to 2017. But the paper later states that there is high post-larval distribution and high density of juvenile *P. monodon*. In addition, a recent survey of *P. monodon* fishers reported a decline in catches over the last 30 years—on average, fishers are currently catching about 10 large shrimp (200 g) per day (D. Leadbitter and Peet, C., 2020). Detailed evaluations of *P. monodon* stock status throughout Indonesian waters were not readily available. According to a recent WWF Indonesia evaluation of the *P. monodon* fishery in the East Aceh fishery management area (WPP) 571, the stock is overexploited (WWF Indonesia, 2020, citing Suman et al. 2018). Adult populations (i.e., broodstock) are "very small" and, at least partly, the result of "excessive fishing of tiger prawn broodstock," leading to the overexploited conditions of the *P. monodon* fishery overall (Damora, A. 2022). The continued degradation of mangrove ecosystems along Sumatra also hinders the availability of healthy nursery grounds for the species (WWF Indonesia, 2020).

In contrast, there is some circumstantial evidence indicating that the *Penaeid* fishery is rebounding and productive; for example, the decline in *P. monodon* aquaculture production since 2000 is causing some speculation that the wild population may be recovering due to the lower demand for broodstock (pers comm, FUI, 2021). According to the MMAF (pers comm, 2021), the *Penaeid* fishery is underutilized, with a total of ≈252,000 MT caught out of a potential of 315,000 MT, of which ≈22% is likely *P. monodon.* No other context was provided, so it is unclear how the estimation of potential catch is determined or how much of each species is landed.

As for improvement of this fishery, there is one known FIP program in South Kalimantan.[130] Seafood Watch is also actively working with researchers in Indonesia to develop a *P. monodon* stock health assessment, but these efforts are only in the beginning stages as of September 2024. In addition, according to personal communications (Anonymous, 2023), the implementation of a Sustainable Fisheries Management Action Plan is in development.

As for alternative sources for *P. monodon*, it is important to note that there are recent efforts to develop a domesticated *P. monodon* broodstock supply in Indonesia and subsequent SPF post-larvae. In February 2020, Bong Tiro entered a partnership to distribute Moana black tiger shrimp broodstock and post-larvae (Shrimp Insights, 2022b). These are closed life-cycle black tiger shrimp, and the post-larvae are now available and actively being grown in Sulawesi, Java, and Kalimantan (Shrimp Insights, 2022b) (pers comm, Susanto and Wibowo, 2024). Data on the number of domesticated *P. monodon* broodstock being used (or the percentage of the total broodstock supply) are not readily available, and the majority are still considered to come from the wild.

---

[130] https://www.fishsource.org/fishery_page/5746

Overall, because nearly all black tiger prawn broodstock are sourced from the wild, and the ecological sustainability of the fishery is considered overexploited, the score for *P. monodon* Criterion 8X—Source of Stock is –10 out of –10.

Conclusions and Final Score

Nearly all black tiger prawn broodstock are sourced from the wild, and the status of the wild *P. monodon* stock is considered to be overexploited, so the score for *P. monodon* in Criterion 8X—Source of Stock is –10 out of –10. For *L.* vannamei, with no use of wild-caught broodstock (or PL), the final score for Criterion 8X—Source of Stock is a deduction of 0 out of –10.

Criterion 9X: Wildlife and Predator Mortalities

Impact, unit of sustainability and principle

- Impact: mortality of predators or other wildlife caused or contributed to by farming operations
- Sustainability unit: wildlife or predator populations
- Principle: preventing population-level impacts to predators or other species of wildlife attracted to farm sites.

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

Criterion 9X Summary: All Species and Production Systems

Wildlife and predator mortality parameters	Score
C9X Wildlife and predator mortality Final Score (0–10)	**–6**

Brief Summary

There is little information or data available on the interactions and/or potential mortalities of wildlife on shrimp farms in Indonesia. From a regulatory perspective, the Indonesian Act on the conservation of biological resources and their ecosystems (Act No. 5 of 1990) and Regulation No. 20/MENLHK/SETJEN/KUM.1/6/2018 are the major legislative frameworks intended to protect more-vulnerable species from any lethal control; however, enforcement is reportedly limited. Regulatory measures or management guidance for other species (i.e., those not necessarily in danger of extinction) were not readily available. Indonesia is a biodiversity center, and aquaculture is associated with threats to 186 species, according to the IUCN; however, it is unclear how many of these species, if any, are affected by day-to-day operations of the farms (as opposed to habitat loss or alteration during farm construction). Many of the animals known to interact with farms (e.g., lizards, turtles, snakes, birds, crustaceans, finfish, cats, dogs, goats, and boar) can be deterred or excluded by simple fences, barriers, or netting, and shrimp farms are generally known to use them. There is limited evidence to suggest that any lethal controls are used, although the use of piscicides or crustacides (i.e., saponin, crustacide, and/or nuvet) in influent waters may be common to kill fish or crustacea that may be pathogen carriers or predators. Overall, given the significant biodiversity of Indonesia and the limited readily available information or data regarding wildlife interactions or mortalities, the risk assessment must be used on a precautionary basis. Therefore, although there are known regulatory measures in place that aim to limit wildlife mortalities, enforcement is reportedly weak and there are no data available on interactions or mortalities. Thus, the final score for Criterion 9X—Wildlife Mortalities is –6 out of –10.

Justification of Rating

Shrimp farms potentially affect a variety of species during their initial construction (broader habitat impacts due to land-use changes are assessed in Criterion 3—Habitat) and during routine operations. Regarding the latter, shrimp farming often requires the control of pests and predators, which can affect the cultured shrimp directly through predation and indirectly through competition for resources such as food (FAO, 1986) or the introduction of diseases (Nguyen et al., 2021).

There do not appear to be any readily available data from Indonesia describing predator and wildlife interactions at farms, mortality rates, or any direct evidence (or lack thereof) of population impacts to affected species. Also, any information that is available does not distinguish between different farmed shrimp species (*P. monodon* and *L. vannamei*) and/or production systems (extensive, semi-intensive, and intensive). Therefore, with low data availability (score of 2.5 out of 10 in Criterion 1—Data), the risk assessment is used. To assess the potential risk of shrimp farm operations causing wildlife mortalities in Indonesia, this criterion describes the known regulations protecting wildlife species and shrimp farm interactions, the species known to predate or compete with farmed shrimp, and the known farm practices.

Regulations

The Indonesian Act on the conservation of biological resources and their ecosystems (Act No. 5 of 1990) creates the general framework for wildlife protections, but focuses primarily on that framework and lacks strong continuity with other environmental laws and species-specific protections (Apriyani, L., et al., 2018). Act No.5/1990 does establish a legal framework for designated protected animals (e.g., in danger of extinction) and precludes the lethal take of these species, among other stipulations (e.g., the take of eggs, the selling of skin or body parts, and the transport of live protected species) (Apriyani, L., et al., 2018).

The Ministry of Environment and Forestry (MOEF) issued Regulation No. 20/MENLHK/SETJEN/KUM.1/6/2018 to specifically address plant and animal species protection. This regulation complements Act No. 5/1990 by designating protected species, based on scientific evidence and population changes. In addition, Ministerial Regulation Number P.106 of 2018[131] outlines the reasons for including species on this protected list, encompassing conservation goals, international agreements, and sustainable resource use. At the time of publication, the regulation (P.106 of 2018) lists over 900 protected plant and animal species.

To help assure that national development and activities do not negatively affect ecosystems and the environment, Government Regulation Number 7 of 1999[132] takes a multipronged approach to conservation, aiming to ensure species sustainability, to prevent extinction, and to maintain ecological balance. This regulation outlines management practices for flora and fauna, including species documentation, monitoring, and tailored protection measures. It also emphasizes that development projects must not negatively affect wildlife or habitats. Complementing Regulation No. 7 of 1999 is Law Number 32 of 2009, concerning Environmental Protection and Management. It establishes a comprehensive framework for environmental protection in Indonesia but is not relevant for species-level protections.

Finally, Government Regulation Number 28 of 2011[133] establishes guidelines for managing designated nature reserves (KSAs) and nature conservation areas (KPAs) in Indonesia. These protected areas serve various purposes, from strict preservation of ecosystems to sustainable use with conservation measures.

---

[131] https://jdih.maritim.go.id/id/peraturan-menteri-lingkungan-hidup-dan-kehutanan-no-p106menlhksetjenkum1122018-tahun-2018

[132] https://peraturan.bpk.go.id/Details/54143/pp-no-7-tahun-1999

[133] https://peraturan.bpk.go.id/Details/5157

The regulation covers management plans, cooperation, buffer zones, funding, and community involvement in these protected areas. A comprehensive map or explanation of where these areas are located and where shrimp farms are located was not readily available; however, it appears that shrimp farms would not be allowed to develop within these areas.

Overall, Indonesia has a complex legal framework for species and ecosystem protection in a decentralized governance scheme. These regulations work together to achieve conservation goals across different levels, from individual species to entire ecosystems. Despite the numerous regulations highlighted previously, there does not appear to be any additional legal framework that prohibits or controls any lethal take of wildlife species[134] besides the species protected through special designations. Examples from other countries include the need for farmers to apply for a permit for any lethal wildlife controls.

Regarding enforcement, there are numerous recent examples relating to turtle egg harvests.[135] But the enforcement effectiveness of protected species in general has been considered limited within the recent past (Wibisana, A.G., and Nuning, W. P., 2018) (Apriyani, L., et al. 2018).

Other forms of wildlife protections include shrimp farm certifications such as the Aquaculture Stewardship Council (ASC).[137] The ASC standard for shrimp farms prohibits the lethal control of IUCN red-listed species (e.g., protected, threatened, or endangered species), which is consistent with Indonesian law. But in total, there are just five shrimp farms in Indonesia that are ASC certified. Also, the IndoGAP standard for shrimp farming does prescribe farm practices for predator avoidance or wildlife protections. According to the CBIB (BSN, 2022), any animal control must be done in a "friendly way," but details are not described. Other industry guidance (GQSP, 2023; MMAF, 2021) recommends applying pond water treatment with saponin to rid pests before stocking, installation of 0.5–4 mm filters, and installation of pest deterrents (e.g., crab protection devices, bird deterrents, and safety fences). Therefore, there appear to be wildlife regulations (e.g., no lethal control) for species that are protected, although the enforcement may be limited, while the regulations for unprotected species are unclear.

Common Wildlife Species

As noted in Criterion 3—Habitat, Indonesia is considered a "megadiverse" country, and aquaculture is associated with threats to 186 species, according to the IUCN; however, it is unclear how many of these species, if any, are affected by day-to-day operations of the farms as opposed to land-use changes during farm construction.

In general, predators on shrimp farms that may feed directly on shrimp include lizards, snakes, birds, finfish, and mammals (FAO, 1986) (pers comm, MMAF, Pratiwi, FUI, Faturakhmat, JALA tech, and GQSP UNIDO, 2021). Examples from the Biodiversity-Inclusive Environmental Impact Assessments (B-EIA) from

---

[134] Government Regulation Number 7 of 1999 concerning the Preservation of Plant and Animal Species, Article 26 addresses situations where animals threaten human life outside their habitat. It allows for capture and release in their native habitat, relocation to a conservation institution, or, as a last resort, euthanasia by an authorized officer.

[135] a) https://news.detik.com/berita/d-4941977/polisi-tangkap-sindikat-penjual-telur-penyu-hijau-ke-singapura-malaysia, b) https://imic.bakamla.go.id/berita/details/291/satpolair-gagalkan-penyelundupan-2-000-butir-telur-penyu-ilegal, c) https://www.merdeka.com/peristiwa/polisi-tangkap-penjual-telur-penyu-di-samarinda-197-butir-telur-disita.html

[137] www.asc-aqua.org

the few shrimp farms certified to the Aquaculture Stewardship Council (ASC) list 24 species that interact with farms (pers comm, Anonymous, 2021). These include monitor lizards, turtles, birds, monkeys, boar, frogs, and snakes, among which the hawksbill turtle (*Eretmochelys imbricata*) is "Critically Endangered," the box turtle (*Cuora amboinensis*) is "Vulnerable," and the red-necked stint (*Calidris ruficollis*) and the Javan plover (*Charadrius javanicus*) are "Near Threatened."

Farm Practices

Through personal communications with Indonesian stakeholder groups, some wildlife exclusion farm practices were shared, which from the farmer's perspective are primarily an aspect of biosecurity (i.e., preventing the entry of potential pathogen carriers to the farm). For semi-intensive and intensive ponds, fences may be put up around ponds, screens are installed at the inlet and outlets, bird netting may cover ponds, crab protection devices may be implemented, and bird scaring devices may be installed (pers comm, MMAF, Faturakhmat, GQSP UNIDO, JALA tech, FUI, CPP, 2021). Of the animals listed previously, many can be deterred by simple fences, barriers, or netting (including on water intakes), especially with small intensive and semi-intensive farms. On larger extensive farms, some of these methods may become less practical.

After reviewing all five shrimp farms in Indonesia that are ASC certified, two had documented observations of an IUCN-listed protected species on the farm premises, and have a worker training program to identify, monitor, and implement mitigation strategies to limit any potentially harmful interactions.[138] Some common farm deterrents used on certified farms include netting or screens over and around ponds and water inlets.

There is some possibility of direct lethal control of aquatic species in influent waters (i.e., fish and crustaceans that present a predation or biosecurity risk) using chemicals such as saponin, crustacide, and/or nuvet (see Criterion 4—Chemical Use), though how common these practices are is unknown. Traditional (extensive) ponds reportedly do not install these types of biosecurity/infrastructure technologies or treat pond water as frequently (pers comm, MMAF, 2021) (Delphino et al. 2022).

Conclusions and Final Score

There is little information or data available on the interactions and/or potential mortalities of wildlife on shrimp farms in Indonesia. From a regulatory perspective, the Indonesian Act on the conservation of biological resources and their ecosystems (Act No. 5 of 1990) and Regulation No. 20/MENLHK/SETJEN/KUM.1/6/2018 are the major legislative frameworks intended to protect more-vulnerable species from any lethal control; however, enforcement is reportedly limited. Regulatory measures or management guidance for other species (i.e., those not necessarily in danger of extinction) were not readily available. Indonesia is a biodiversity center, and aquaculture is associated with threats to 186 species, according to the IUCN; however, it is unclear how many of these species, if any, are affected by day-to-day operations of the farms (as opposed to habitat loss or alteration during farm construction). Many of the animals known to interact with farms (e.g., lizards, turtles, snakes, birds, crustaceans, finfish, cats, dogs, goats, and boar) can be deterred or excluded by simple fences, barriers, or netting, and shrimp farms are generally known to use them. There is limited evidence to suggest that any lethal controls are used, although the use of piscicides or crustacides (i.e., saponin, crustacide, and/or nuvet) in influent waters may be common to kill fish or crustacea that may be pathogen carriers or predators. Overall, given the significant biodiversity of Indonesia and the limited readily available

---

[138] PT. Surya Windu Kartika, audit report August 23, 2022 https://www.asc-aqua.org/find-a-farm/ASC01514/ and PT Ketah Makmur audit report January 26, 2023 https://www.asc-aqua.org/find-a-farm/ASC01553/

information or data regarding wildlife interactions or mortalities, the risk assessment must be used on a precautionary basis. Therefore, although there are known regulatory measures in place that aim to limit wildlife mortalities, enforcement is reportedly weak and there are no data available on interactions or mortalities. Thus, the final score for Criterion 9X—Wildlife Mortalities is –6 out of –10.

Criterion 10X: Introduction of Secondary Species

Impact, unit of sustainability and principle

- Impact: movement of live animals resulting in introduction of unintended species
- Sustainability unit: wild native populations
- Principle: avoiding the potential for the accidental introduction of secondary species or pathogens resulting from the shipment of animals.

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

Criterion 10X Summary: *L. vannamei*—all production systems

C10X Introduction of Secondary Species parameters	Value	Score
F10Xa Percent of production reliant on trans-waterbody movements (%)	100	0
Biosecurity score of the source of animal movements (0–10)		10
Biosecurity score of the farm destination of animal movements (0–10)		4
Species-specific 10X score		0
C10X Introduction of Secondary Species Final Score		**0**

Criterion 10X Summary: *P. monodon*—extensive production systems

C10X Introduction of Secondary Species parameters	Value	Score
F10Xa Percent of production reliant on trans-waterbody movements (%)	90	0
Biosecurity score of the source of animal movements (0–10)		1
Biosecurity score of the farm destination of animal movements (0–10)		8
Species-specific 10X score		–1.8
C10X Introduction of Secondary Species Final Score		**–1.8**

Brief Summary

Production of *L. vannamei* in Indonesia is entirely reliant on the trans-waterbody movements of live shrimp, either from international breeding centers (in the form of adult broodstock or post-larvae) to hatcheries or broodstock multiplication centers (BMC) in Indonesia, or of adult broodstock from BMCs and domestic breeding programs to hatcheries across Indonesia. The subsequent movements of post-larvae from hatcheries to relatively local grow-out ponds are not considered here. The score for Factor 10Xa is 0 out of 10. With high biosecurity of the sources, and moderate biosecurity at the destination hatcheries, the score for Factor 10Xb is 10 out of 10. Thus, the combined final score for Criterion 10X for *L. vannamei* is a deduction of 0 out of –10.

Production of *P. monodon* depends largely on the movements of wild-caught broodstock (considered to be landed in Aceh in Sumatra) to hatcheries across Indonesia. With 90% of production considered dependent on these movements (i.e., all production outside Sumatra), the score for Factor 10Xa is 0 out of 10. Given the open nature of the wild fisheries for *P. monodon*, it is challenging to prevent a secondary species from being unintentionally transported with broodstock movements across Indonesia, despite the biosecurity measures in place. But it appears that the destination hatcheries (and the quarantine controls along the supply chain from port to hatchery) implement several biosecurity controls and quarantine procedures that limit the potential risk of an unintentionally transported secondary species escaping into a new environment (e.g., zero exchange tank quarantine upon arrival to hatcheries and PCR tests). The score for Factor 10Xb is decided by the higher score of either the source or the destination of movements (i.e., high biosecurity at either the source or the destination of movements can prevent the escape of a secondary species into the environment). Therefore, the score for *P. monodon* is based on the high biosecurity at the destination (hatcheries), and is 8 out of 10. Thus, the combined final score for Criterion 10X for *P. monodon* is a deduction of –1.8 out of –10.

Justification of Rating

The concern regarding the introduction of secondary species during live animal movements is perhaps exemplified by the rapid international spread of various shrimp pathogens, and Arulmoorthy et al. (2020) consider that the shipment of broodstock and post-larvae from one geographical region to another has often resulted in the spread of diseases. For example, according to Lee et al. (2022), the first reports of white spot syndrome virus (WSSV) in penaeid shrimp occurred in China and Taiwan in 1992, then spread to Korea and Japan (1993), Vietnam and Thailand (1994), and Malaysia and Indonesia (1995). WSSV also occurred in America (Latin America, such as Ecuador, Mexico, and Brazil, in 1999; and North America in 1995), the Middle East (2001), Africa (such as Mozambique and Madagascar in 2011), and most recently at an Australian shrimp farm in 2016. Lee et al. (2022) also considered that the ongoing translocation of broodstock that is unscreened or inadequately tested for WSSV has led to the spread of WSSV back to Asia from the Americas. This emphasizes the importance of biosecurity of trans-waterbody live animal shipments. Because of the differing characteristics of the two species assessed here, they are discussed and scored separately as follows.

Factor 10Xa: International or trans-waterbody live animal shipments

This factor determines the approximate percentage of production reliant on the ongoing trans-waterbody movement of broodstock and post-larvae (PLs). Trans-waterbody movement is defined as the source waterbody being ecologically distinct from the destination waterbody, such that the animal movements represent a risk of introducing species not native to or present in the destination waterbody.

L. vannamei

Indonesia imports nearly 100% of its *L. vannamei* broodstock either as adults (≈39% by market share) or as parent post-larvae (PPL) (≈60% by market share[139]) (Shrimp Insights, 2022a). The industry is quite consolidated. According to Shrimp Insights (2022a), it is estimated that 96% of broodstock are imported from four companies: Kona Bay–Hendrix Genetics, Shrimp Improvement Systems (SIS), SyAqua, and American Penaid, Inc. (API) (Figure 12).

---

[139] Determination of market share and total market of broodstock is extrapolated from trade statistics, where “broodstock import numbers are calculated by dividing the total value of broodstock imports in dollars by $55, which we [Shrimp Insights] consider here to be the average price per animal” (Shrimp Insights, 2020).

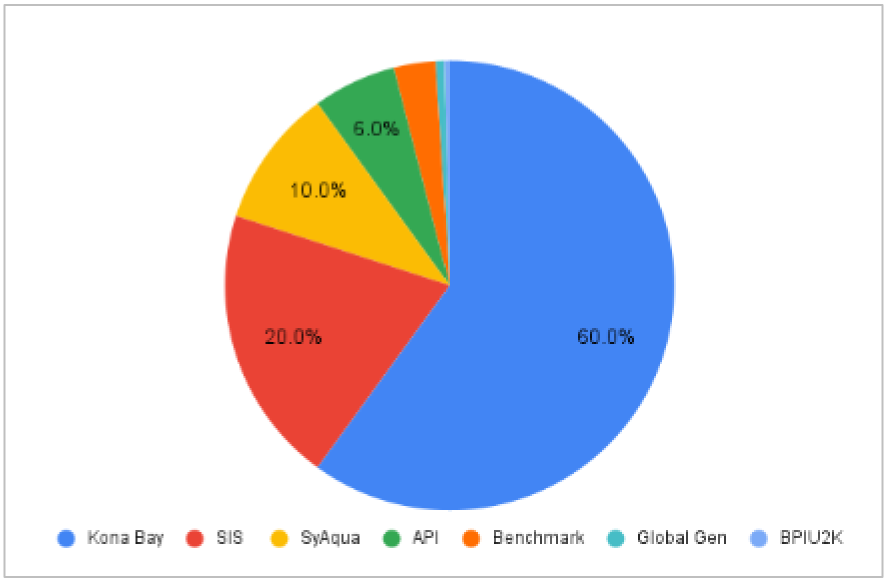

Figure 12: Market shares of Indonesia's broodstock suppliers. Source: Shrimp Insights, 2022a.

There are also some *L. vannamei* breeding centers in Indonesia owned by the government and by private companies. The Karangasem-Bali Superior Shrimp Broodstock Production Center (BPIU2K) is a government facility that has been in operation since 2014 (Shrimp Insights, 2020), and Global Gen is a private broodstock facility operating in Lombok. The combined market share of these companies is estimated to be < 4%, and although these domestically produced broodstock are not subject to international movements, they will be moved across Indonesia when delivered to hatcheries.

Therefore, there are three scenarios of *L. vannamei* movements to consider:

1. The import of adult broodstock shrimp, sourced from international breeding centers and delivered to hatcheries in Indonesia.
2. The import of broodstock as post-larvae,[140] sourced from international breeding centers and delivered to broodstock multiplication centers (BMC) in Indonesia, where they are grown to adult size.
3. The movements of adult broodstock, sourced from BMCs in Indonesia and domestic breeding centers in Indonesia and delivered to hatcheries in Indonesia.

As discussed in the following, a fourth category is the movement of post-larvae sourced from hatcheries in Indonesia and delivered to grow-out farms in Indonesia, but these movements are not considered trans-waterbody.

---

[140] These are typically called Parent Post Larvae (PPL).

Using the data from Figure 12 and the analysis in Shrimp Insights (2022a), the following scales of movements can be approximated:

- Scenario 1—The companies SIS, SyAqua, APL, and Benchmark all import adult broodstock. According to Figure 12, this represents approximately 39% of the total *L. vannamei* broodstock used in Indonesia.
- Scenario 2—The Kona Bay company in Indonesia imports PPL from international breeding centers and delivers them to two BMC facilities in Indonesia. This represents 60% of the total *L. vannamei* broodstock used in Indonesia.
- Scenario 3—After growing to spawning size, the Kona Bay broodstock (imported as PPL) is subsequently distributed to hatcheries across Indonesia. The two domestic breeding programs, Global Gen and BPIJ2K, also distribute their broodstock to hatcheries across Indonesia. Of the total *L. vannamei* broodstock used in Indonesia, 61% are moved this way.

These figures show that there is a high dependence on imported broodstock and/or on movements of broodstock across Indonesia, with some animals being moved twice. Therefore, the industry appears entirely reliant (100%) on trans-waterbody movements, and the score for Factor 10xa—international or trans-waterbody animal shipments is 0 out of 10.

P. monodon

P. monodon is sourced from wild-caught broodstock fisheries in Indonesia (see Criterion 8X—Source of Stock). Official statistics describing the *P. monodon* broodstock fishery (e.g., landing area and fishery location) are not readily available, but it appears, based on personal communications, that the majority of *P. monodon* broodstock landings occur in Aceh (pers comm, Faturakhmat, 2023) (pers comm, Kokarkin and Widigdo, 2024). For the purposes of this assessment, it is assumed that all *P. monodon* broodstock are landed in Aceh.

Therefore, after landing *P. monodon* broodstock in Aceh, the subsequent movement to broodstock centers outside of Aceh is considered to be trans-waterbody movement of live animals. According to production estimates from Statistik-KKP (see Table 2 in the Introduction), Aceh accounted for 10% of total *P. monodon* production; therefore, it is estimated that the remainder, roughly 90% of *P. monodon* broodstock, is shipped to areas outside of Sumatra. This is considered trans-waterbody movement, resulting in a score for Factor 10xa—international or trans-waterbody animal shipment of 0 out of 10.

Post-larvae of both species are subsequently moved from hatcheries to grow-out ponds, but given the greater dispersal of hatcheries throughout Indonesia that are typically located near the primary grow-out regions, these movements are not considered here to be trans-waterbody.

Factor 10Xb: Biosecurity of source/destination

This factor evaluates the risk of unintentionally including secondary species during trans-waterbody movement of *L. vannamei* and *P. monodon* and the risk of releasing them upon arrival. It considers the biosecurity of the source and destination of movements.

L. vannamei

As defined previously, the three scenarios of *L. vannamei* movements have four different potential sources or destinations:

- International breeding centers that export broodstock (as adults or PPL)

- Broodstock multiplication centers (BMC) in Indonesia that receive PPL and distribute adult broodstock to hatcheries. These are considered to have similar biosecurity practices to the domestic breeding centers in Indonesia that distribute broodstock to hatcheries.
- Hatcheries in Indonesia that receive broodstock (and produce post-larvae for grow-out).

The biosecurity of each of these locations as a source or destination is described as follows. For simplification, the BMCs and the domestic breeding centers in Indonesia are considered to have similar biosecurity practices. Because of the domestic breeding centers' minor scale of production (approximately 1% of the total broodstock), they are not discussed separately.

Export company: Based on Shrimp Insights (2022a), four major companies dominate the shipments of either adult broodstock or PPL to Indonesia from the United States. These facilities all produce specific pathogen-free (SPF) breeding lines in biosecure locations. Although never entirely biosecure, these tank-based recirculation facilities test their stocks extensively during production and before shipment, and are considered to have a low risk of introducing secondary species at the source of movements (i.e., before entering Indonesia). Also, according to Law No. 21 of 2019 regarding animal and plant quarantine certificates, all imports of live animals (e.g., broodstock) must be accompanied with a health certificate certifying that the broodstock are SPF from the country of origin, and they may also be inspected at Indonesia's quarantine entry points. Thus, these sources are considered fully biosecure and score of 10 out of 10, with a low level of concern for the introduction of secondary species at the source of movements.

BMC in Indonesia: Broodstock multiplication centers (BMC) have recently developed in Indonesia and appear to be primarily owned and operated by Kona Blue–Hendrix Genetics (Shrimp Insights, 2022a). These facilities receive post-parent larvae (PPL) from export companies (i.e., Kona Blue–Hendrix Genetics) and grow the post-larvae into adult broodstock to be later shipped to hatcheries. These facilities are considered highly biosecure, with biosecurity attributes consistent with the export company description, and they maintain SPF life cycles. Thus, these sources are considered fully biosecure and score of 10 out of 10, with a low level of concern for introductions or losses of secondary species when sending or receiving shipments. As noted, the characteristics of the BMCs are considered to be similar to those of the domestic breeding programs in Indonesia.

Hatchery in Indonesia: As a destination of movements, there appears to be a range of *L. vannamei* hatchery biosecurity practices in Indonesia. This may be the result of differing structures that exist, such as size (e.g., backyard, medium-, or large-scale), and/or the ownership structure (e.g., owned by feed companies, local government, or farms) (pers comm JALA, Pratiwi, Anonymous, 2021).

On the one hand, the biosecurity of aquaculture hatcheries in Indonesia is reportedly comprehensive, with 131 certified to the IndoGAP standard (Dahuri, R., 2020), of which 32 are *L. vannamei* hatcheries (pers comm, 2021). IndoGAP requirements for hatcheries (2014) detail the biosecurity protocols, which cover design and layout, facility cleaning, water maintenance, broodstock control, larvae control, feed guidance, and personnel guidance. Each stage emphasizes and details control points to limit the risk or spread of disease. "Design and layout" details the need for water filtration, wastewater treatment ponds (WWTP), proper storage, and access to sterile and nonsterile rooms. For "facility cleaning," there is an emphasis on disinfecting equipment, infrastructure, avoidance of cross-contamination of equipment, and 1–2 weeks drying of tanks between cycles. Water needs to be disinfected, with sampling for AHPND. Feed for larvae (i.e., plankton, artemia, worms, clams, squid) must not be sourced from countries with AHPND, and each batch must be sampled. Personnel are limited between areas, including visitors and employees, with footbaths between distinct areas. There is also Directorate General Regulation No.165-2019 Technical Guidelines for Preventing AHPND, which appears to be a standard operating procedure for hatcheries to understand the importance of biosecurity to limit the potential spread of AHPND in Indonesia. In general, hatcheries compliant to these types of practices sound biosecure.

On the other hand, there is limited readily available information about *L. vannamei* hatcheries that are not IndoGAP-certified in Indonesia. It is also unclear what proportion of the industry is supplied by IndoGAP and non-IndoGAP hatcheries. Regardless, pathogens stemming from hatcheries appear to be an issue. In a webinar, Haris Muhtadi (CEO of Indonesia Shrimp Club) confirmed this concern, stating that hatcheries must conduct a PCR test [of PLs] for viruses before releasing to farmers, because many of the viruses originate from the hatchery.

As a result, hatcheries in Indonesia are considered to have a moderate risk of secondary species escapes. Some hatcheries implement best management practices (i.e., IndoGAP-certified farms) (score of 6) and other hatcheries operate without best management practices (score of 2). The resulting interim score is 4 out of 10.

Conclusion—L. vannamei
Although the eventual destinations of broodstock movements at the hatcheries are considered to have moderate biosecurity, it can be seen from the preceding analysis that all the sources of movements have high biosecurity (scoring 10 out of 10). Factor 10Xb is decided by the higher score of either the source or the destination of movements (i.e., high biosecurity at either the source or the destination of movements can prevent the escape of a secondary species into the environment). Therefore, the score for Factor 10Xb is 10 out of 10.

P. monodon
As discussed in Factor 10Xa, the movements of *P. monodon* that are in the scope of this assessment are of broodstock from wild capture fisheries (and the landing port in Aceh) to hatcheries across Indonesia. The biosecurity characteristics of the source and destination are described as follows.

Port (source): Once landed, wild *P. monodon* broodstock must abide by quarantine laws and receive a health certificate before any shipment, or it will be denied at the importing island's quarantine entry point. A health certificate includes a declaration that the animal is free of specified diseases (Regulation No. 15 of 2002 Concerning Fish Quarantine). The general quarantine process for landed broodstock was described through personal communications. The first step of the quarantine procedure is placing broodstock in a bag filled with filtered (40–50 micron) coastal water (salinity of 30–31 ppt) and chlorine (20 ppm) to help reduce the chances of bacterial, parasitic, or viral disease carriers within the bag (Kokarkin and Widigdo, 2024). Broodstock is held for about 4 hours, then driven to the Polonia airport in North Sumatra (Kokarkin and Widigdo, 2024). Once at the airport, broodstock is held in "boxes" and must follow the quarantine procedure: inspection, held in isolation facilities for 12 hours, and a PCR test for diseases (Kokarkin and Widigdo, 2024). If the inspection and PCR tests are favorable, then the broodstock is repackaged and flown to either Sulawesi, Java (Jakarta or Semarang), or Kalimantan (pers comm, Pratiwi, MMAF, FUI, GQSP UNIDO, 2021) (Leadbitter, D. and Peet, C., 2020) (pers comm Kokarkin and Widigdo, 2024). Although *P. monodon* is sourced from the wild, there are multiple biosecurity controls to test the broodstock individually, along with monitoring and evaluation of the broodstock health and potential vectors that the broodstock may be carrying. The SFW standard scores any wild-caught broodstock as a "high concern" (score 0 out of 10) for source biosecurity; however, the many biosecurity measures in place (e.g., monitoring and testing) demonstrate best practices and result in an intermediate score of 1 out of 10.

Hatchery (destination): Once broodstock is transported from Aceh to the hatchery (i.e., Java, Kalimantan, Sulawesi), the exterior of the bags that broodstock was transported in is dipped into an iodine solution (200 ppm) before being placed into a zero-discharge quarantine tank (pers comm, Kokarkin and Widigdo, 2024). Some hatcheries will conduct another PCR test for any possible diseases (pers comm, Kokarkin and Widigdo, 2024). If the test is positive, the broodstock is removed and disposed of; if negative, the broodstock is dipped in formalin (50–100 ppm) and iodine (20 ppm) before transferring into the hatchery operation (pers comm, Kokarkin and Widigdo, 2024). This suggests a high level of biosecurity of the hatcheries receiving wild *P. monodon* broodstock, and the score is 8 out of 10.

Conclusion—P. monodon
Given the open nature of the wild fisheries for *P. monodon*, it is challenging to prevent a secondary species from being transported with broodstock movements across Indonesia, despite the biosecurity measures in place. But it appears that hatcheries (and the quarantine controls along the supply chain from port to hatchery) implement several biosecurity controls and quarantine procedures that limit the potential risk of secondary escapes (e.g., zero exchange tank quarantine upon arrival to hatcheries and PCR tests). The score for Factor 10Xb is decided by the higher score of either the source or the destination of movements (i.e., high biosecurity at either the source or the destination of movements can prevent the escape of a secondary species into the environment). Therefore, the score for *P.* monodon is based on the high biosecurity at the destination (hatcheries) and is 8 out of 10.

Conclusions and Final Score
Production of *L. vannamei* in Indonesia is entirely reliant on the trans-waterbody movements of live shrimp, either from international breeding centers (in the form of adult broodstock or post-larvae) to hatcheries or broodstock multiplication centers (BMC) in Indonesia, or of adult broodstock from BMCs and domestic breeding programs to hatcheries across Indonesia. The subsequent movements of post-larvae from hatcheries to relatively local grow-out ponds are not considered here. The score for Factor 10Xa is 0 out of 10. With high biosecurity of the sources, and moderate biosecurity at the destination hatcheries, the score for Factor 10Xb is 10 out of 10. The combined final score for Criterion 10X for *L. vannamei* is a deduction of 0 out of –10.

Production of *P. monodon* depends largely on the movements of wild caught broodstock (considered to be landed in Aceh in Sumatra) to hatcheries across Indonesia. With 90% of production considered dependent on these movements (i.e., all production outside Sumatra), the score for Factor 10Xa is 0 out of 10. Given the open nature of the wild fisheries for *P. monodon*, it is challenging to prevent a secondary species from being unintentionally transported with broodstock movements across Indonesia, despite the biosecurity measures in place. But it appears that the destination hatcheries (and the quarantine controls along the supply chain from port to hatchery) implement several biosecurity controls and quarantine procedures that limit the potential risk of an unintentionally transported secondary species escaping into a new environment (e.g., zero exchange tank quarantine upon arrival to hatcheries and PCR tests). The score for Factor 10Xb is decided by the higher score of either the source or the destination of movements (i.e., high biosecurity at either the source or the destination of movements can prevent the escape of a secondary species into the environment). Therefore, the score for *P. monodon* is based on the high biosecurity at the destination (hatcheries) and is 8 out of 10. Thus, the combined final score for Criterion 10X for *P. monodon* is a deduction of –1.8 out of –10.

Acknowledgements

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

Thank you to the reviewers and participants of this assessment who helped immensely with sharing industry documents, insights, and for careful consideration and review of the assessment. In particular, thank you to:

Trini Pratiwi

Paul Bulcock

Ita Sualia

References

ADB / ACIAR / AwF / BRR / DKP / FAO / GTZ / IFC / MMAF / NACA / WWF. 2007. Practical manual on better management practices for tambak farming in Aceh. Published by Asian Development Bank ETESP, Australian Centre for International Agriculture Research, Food and Agriculture Organization of the United Nations, International Finance Corporation of the World Bank Group, Banda Aceh. June 2007. Available online at: http://library.enaca.org/Shrimp/publications/e014_bmp_book_english.pdf

Adyasari, D., Pratama, M. A., Teguh, N. A., Sabdaningsih, A., Kusumaningtyas, M. A., & Dimova, N. (2021). Anthropogenic impact on Indonesian coastal water and ecosystems: Current status and future opportunities. *Marine Pollution Bulletin*, *171*, 112689. https://www.sciencedirect.com/science/article/abs/pii/S0025326X21007232

Afero, F. (2009). Survey report: Current status of P. Vannamei in Nanggroe Aceh Darussalam. WWF Program (Aceh). 10pp.

Alangkara, D. and Milko, V. (2022) *Living amid flood in Indonesia, unable to leave* https://apnews.com/article/floods-indonesia-java-climate-and-environment-bc4433924c7815e4d913f868f922c201

Alongi, D. M. (2008). Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. *Estuarine, coastal and shelf science*, *76*(1), 1-13. https://www.sciencedirect.com/science/article/abs/pii/S0272771407003915

Amelia, F., Yustiati, A., & Andriani, Y. (2021). Review of shrimp (Litopenaeus vannamei (Boone, 1931)) farming in Indonesia: Management operating and development. *World Scientific News*, *158*, 145-158.

Andriyono, S., Kusumaningrum, F., & Suciyono, S. (2022). Analysis Of Antibiotic Residue On Vaname Shrimp (Litopenaeus Vannamei) In Kalipuro Intensive Pond, Banyuwangi. Barakuda'45, 4(2), 180-186. https://jurnal.publikasi-untagcirebon.ac.id/index.php/barakuda45/article/view/274

Anshary, H. and Baxa, D.V., 2017. Multiple viral pathogens occurrence in tiger shrimp (Penaeus monodon) broodstock from Sulawesi coastal waters. Aquaculture, Aquarium, Conservation & Legislation, 10(4), pp.936-950.

Apriyani, L., AR, F. Y., & Erwandi, M. (2018). Comparison of wildlife protection law between Indonesia and the United States. *Hasanuddin Law Review*, *4*(2), 181-193.

Arifanti, V. B. (2020, April). Mangrove management and climate change: a review in Indonesia. In *IOP conference series: earth and environmental science* (Vol. 487, No. 1, p. 012022). IOP Publishing.

Arbon, P.M., Condon, K., Martinez, M.A. and Jerry, D.R., 2022. Molecular detection of six viral pathogens from Australian wild sourced giant black tiger shrimp (Penaeus monodon) broodstock. Aquaculture, 548, p.737651.

Ardjosoediro, I. and Goetz, F. (2007). A value chain assessment of the aquaculture sector in Indonesia. US Agency of International Development (USAID) RAISE Plus IQC Task Order EDH-I-04-05-00004-00 (January 2007).

Arulmoorthy, M.P., Anandajothi, E., Vasudevan, S. and Suresh, E., 2020. Major viral diseases in culturable penaeid shrimps: a review. Aquaculture International, 28(5), pp.1939-1967.

Asian Development Bank. (2016) Indonesia Country Water Assessment. https://www.adb.org/sites/default/files/institutional-document/183339/ino-water-assessment.pdf

Baines, G. and Hariyanto, M., 2002. Indonesia. Pp 131-157 In Biodiversity Planning in Asia. J.E. Carew-Reid (ed), IUCN.

Basorie, Djajanto Warief. (2022) *Indonesia's mangrove restoration bid holds huge promise, but obstacles abound.* Mongabay. https://news.mongabay.com/2022/07/indonesias-mangrove-restoration-bid-holds-huge-promise-but-obstacles-abound/#:~:text=The%20government%20aims%20to%20restore,emissions%20reduction%20target%20for%202030.

Barbier, EB, EW Koch, BR Silliman et al. (2008) Coastal Ecosystem–Based Management with Nonlinear Ecological Functions and Values. Science 319: 321-323.

Bergh, Børsheim KY, Bratbak G, Heldal M . (1989). High abundance of viruses found in aquatic environments. Nature 340: 467–468.

Bosma, R.H, Debrot, D., Rejeki, S., Tonneijck, F., Yuniati, A., W. & Sihombing, W. (2020). Associated Mangrove Aquaculture Farms; Building with Nature to restore eroding tropical muddy coasts. Ecoshape technical report, Dordrecht, The Netherlands. https://www.researchgate.net/profile/Adolphe-Debrot/publication/345105230_Associated_Mangrove_Aquaculture_Farms_Building_with_Nature_to_restore_eroding_tropical_muddy_coasts/links/5f9dbc3192851c14bcf8aa79/Associated-Mangrove-Aquaculture-Farms-Building-wi

Boyd, C. E., McNevin, A. A., Racine, P., Tinh, H. Q., Minh, H. N., Viriyatum, R., & Paungkaeu, D. (2017). Resource use assessment of shrimp, Litopenaeus vannamei and Penaeus monodon production in Thailand and Vietnam. Journal of the World Aquaculture Society 48, 201-226.

Boyd, C.E., Davis, R.P. and McNevin, A.A. (2021a). Comparison of resource use for farmed shrimp in Ecuador, India, Indonesia, Thailand, and Vietnam. Aquaculture, Fish and Fisheries, 1(1), pp.3-15.

Boyd, C.E., Davis, R.P. & McNevin, A.A. (2021b). Perspectives on the mangrove conundrum, land use, and benefits of yield intensification in farmed shrimp production: a review. Journal of theWorld Aquaculture Society. https://doi.org/10.1111/jhwas.12841

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

Briggs, M. (2005). Introductions and movement of two penaeid shrimp species in Asia and the Pacific (No. 476). Food & Agriculture Org.

Budhiman, A.A., Paryanti, T.S. & Sunaryanto, A. (2005). The present status of Penaeus vannamei and other exotic shrimp culture in Indonesia. In: Regional Technical Consultation on the Aquaculture of P. vannamei and Other Exotic Shrimps in Southeast Asia, Manila, Philippines (pp. 42-49). Tigbauan, Iloilo, Philippines : SEAFDEC Aquaculture Department.

Bunting S. W., Roel H. Bosma, Paul A. M. van Zwieten & A. S. Sidik. (2013). Bioeconomic modeling of shrimp aquaculture strategies for the Mahakam Delta, Indonesia, Aquaculture Economics & Management, 17:1, 51-70

Bussarin, A. K. & Unger, J. (2015). PT Centralpertiwi Bahari farm final audit report. Aquaculture Stewardship Council. 69 pp. Available at: http://www.ascaqua.org/upload/3_20150116_PT%20Central%20Proteina%20Prima_PT%20Central%20Pertiwi%20Bahari%20Farm_FINAL.pdf

Bussarin, A. K. & Unger, J. (2015a). PT Centralproteina Prima farm final audit report. Aquaculture Stewardship Council. 68 pp. Available at: http://www.ascaqua.org/upload/3_20150116_PT%20Central%20Proteina%20Prima_PT%20Central%20Proteina%20Prima%20Farm_FINAL.pdf

California Environmental Associates. 2018. “Trends in Marine Resources and Fisheries Management in Indonesia: A 2018 Review”. https://www.ceaconsulting.com/wp-content/uploads/Indonesia-Report-2018-11.9.18-compressed.pdf

Carugati, L., Gatto, B., Rastelli, E., Lo Martire, M., Coral, C., Greco, S., & Danovaro, R. (2018). Impact of mangrove forests degradation on biodiversity and ecosystem functioning. *Scientific reports*, *8*(1), 13298.

CCIF. (2013). Assessment of the Enabling Conditions for Rights-Based Management of Fisheries and Coastal Marine Resources in the Western Pacific. https://s3-us-west-2.amazonaws.com/sfw-images/reportsresources/28315/references/26496.pdf

Chavanich, S., Viyakarn, V., Senanan, W., Panutrakul, S., 2016. Laboratory assessment of feeding-behavior interactions between the introduced Pacific white shrimp Litopenaeus vannamei (Boone, 1931) (Penaeidae) and five native shrimps plus a crab species in Thailand. Aquatic Invasions 11, 67–74. https://doi.org/10.3391/ai.2016.11.1.07

Chellapandian, H., Aadham, M. S., Jaabir, M., & Jeyachandran, S. (2023). Alarming Viral Pathogens in Shrimp Industry and Nanotechnology. In *Nanotechnological Approaches to the Advancement of Innovations in Aquaculture* (pp. 115-126).

Clark Labs. Brackish Pond Aquaculture and Coastal Wetlands from 1999-2020. *Accessed October 2022.* https://www.aquaculture.earth/coastal/index.html

Convention on Biological Diversity. (*no date*) Indonesia. https://www.cbd.int/countries/profile/?country=id

Dahuri, Rokhmin. (2020) The IndoGAP: Strengthening The Indonesian Aquaculture Best Practices for Healthy, Safe, and Environmentally Friendly Aquaculture Products for Consumers. https://indonesianfoodsafety.org/wp-content/uploads/2020/07/Presentation-Prof-Rokhmin-Dahuri-compressed.pdf

Damora, A. (2022). *Results of Landing Data Analysis of Windu Shrimp Penaeus monodon in East Aceh District and Aceh Tamiang District.*

Dao, T. (2020). *Indonesia unlikely to realize ambitious shrimp-sector growth target.* SeafoodSource. Retrieved February 22, 2023, from https://www.seafoodsource.com/news/supply-trade/indonesia-unlikely-to-realize-ambitious-shrimp-sector-growth-target

Delphino, M. K. V. C., Laurin, E., Patanasatienkul, T., Rahardjo, R. B., Hakim, L., Zulfikar, W. G., Burnley, H., Hammell, K. L., & Thakur, K. (2022). Description of biosecurity practices on shrimp farms in Java, Lampung, and Banyuwangi, Indonesia. *Aquaculture*, *556*, 738277. https://doi.org/10.1016/j.aquaculture.2022.738277

De Silva, M.L.I., Ranjula, M., Thanuja, M., Katuwawala, D. dnd Sumanapala, A., 2021. Review On Impacts Of Litopenaeus Vannamei On Aquaculture. Wildlanka Vol.9, No.1, Pp. 149 - 170, 2021

Desrina, D., Prayitno, S. B., Haditomo, A. H. C., Latritiani, R., & Sarjito, S. (2020). Detection of Enterocytozoon hepatopenaei (EHP) DNA in the polychaetes from shrimp ponds suffering white feces syndrome outbreaks. *Biodiversitas Journal of Biological Diversity*, *21*(1).

Determination of Administrative Sanctions. Ministerial Regulation Fisheries and Marine No.31-2021

Dhar, A.K., Cruz-Flores, R. and Bateman, K.S., 2022. Viral diseases of crustaceans. Invertebrate Pathology, p.368.

Dutta, S., Chakrabarty, U., Mallik, A. and Mandal, N., 2015. White spot syndrome virus (WSSV) prevalence associated with disease resistance among wild populations of black tiger shrimp, Penaeus monodon (Fabricius). Aquaculture Research, 46(2), pp.453-461.

Dwiyahreni, A. A., Fuad, H. A., Muhtar, S., Soesilo, T. E., Margules, C., & Supriatna, J. (2021). Changes in the human footprint in and around Indonesia’s terrestrial national parks between 2012 and 2017. *Scientific reports*, *11*(1), 1-14.

Eastman, J. R., & Toledano, J. (n.d.). *Phase 3 Extension to the Mapping of Tropical Pond Aquaculture, Mangroves and Coastal Wetlands*. https://clarklabs.org/wp-content/uploads/2020/12/Phase-3-Extension-to-the-Mapping-of-Tropical-Pond-Aquaculture-Mangroves-and-Coastal-Wetlands-Report-6.pdf

Emerenciano, M.G., Rombenso, A.N., Vieira, F.D.N., Martins, M.A., Coman, G.J., Truong, H.H., Noble, T.H. and Simon, C.J., 2022. Intensification of Penaeid Shrimp Culture: An Applied Review of Advances in Production Systems, Nutrition and Breeding. Animals, 12(3), p.236.

Environmental Law Alliance Worldwide. (2020). Indonesia: Select mangrove laws. https://www.elaw.org/indonesia-select-mangrove-laws

Evan, Y., & Putri, N. E. (2021). *Status of Aquatic Animal Health in Indonesia*. 9. https://repository.seafdec.org.ph/bitstream/handle/10862/6265/EvanY2021.pdf?sequence=1&isAllowed=y

EnviX, Ltd. (No date) Indonesia, General overview of Government Regulation No. 22 of 2021 on Environmental Protection and Management. https://enviliance.com/regions/southeast-asia/id/id-gr22-2021-overall

FAO. (2005-2023). Cultured Aquatic Species Information Programme. Penaeus monodon. Cultured Aquatic Species Information Programme. Text by Kongkeo, H. In: *FAO Fisheries and Aquaculture*

Division [online]. Rome. Updated . [Cited 20 December2023]. https://firms.fao.org/fi/website/FIRetrieveAction.do?dom=culturespecies&xml=Penaeus_monodon.xml

FAO. (2005). Aquaculture topics and activities. Main cultured species. Text by Rohana Subasinghe and David Currie. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 27 May 2005. [Cited 7 August 2015]. http://www.fao.org/fishery/culturedspecies/Penaeus_P. monodon/en

FAO. (2015). "AGP - Fertilizer Specifications." FAO Plant nutrition. Retrieved September 12, 2015, from http://www.fao.org/agriculture/crops/corethemes/theme/spi/plantnutrition/fertspecs/en/

FAO. (2017). Socio-economics of trawl fisheries in Southeast Asia and Papua New Guinea. FAO Fisheries and Aquaculture Proceedings 50. GEF. ISSN 2070-6103.

FAO. (2020). *Global Forest Resources Assessment*. https://doi.org/10.4060/ca9825en

FAO 2022. Indonesia. Text by Skonhoft, A.. Fisheries and Aquaculture Division [online]. Rome. [Cited Tuesday, June 28th 2022]. https://www.fao.org/fishery/en/legalframework/id/en

FAO and MMAF. (2015) *Development Of A Preventive Aquatic Animal Health Protection Plan And Enhancing Capacities To Shrimp Disease Outbreaks In Indonesia.*

Febri, S. P., Purba, F. A., & Gigentika, S. (2022). a. *Aquaculture, Aquarium, Conservation & Legislation*, *15*(4), 2142-2151.

Fernández de Alaiza García Madrigal, R., da Silva, U.D.A.T., Tavares, C.P.D.S. and Ballester, E.L.C., 2018. Use of native and non-native shrimp (Penaeidae, Dendrobranchiata) in world shrimp farming. Reviews in Aquaculture, 10(4), pp.899-912.

Flegel, T. W. (2009). Current Status of Viral Diseases in Asian Shrimp Aquaculture. *Israeli Journal of Aquaculture - Bamidgeh*, *61*. https://doi.org/10.46989/001c.20556

Fish Medicine, 1 Permen-KP (2019).

Florina, P., Hartoyo, S., & Sukardi, S. (2012). Adoption of good management practice (GMP) in small and medium scale vannamei shrimp farms on the north shore of East Java. Jurnal Manajemen & Agribisnis, 9(2), 79-88.

Friess, D. A., Thompson, B. S., Brown, B., Amir, A. A., Cameron, C., Koldewey, H. J., Sidik, F. (2016). Policy challenges and approaches for the conservation of mangrove forests in Southeast Asia. Conservation Biology, 30(5), 933–949. https://doi.org/10.1111/cobi.12784.

Friess, D. A., Rogers, K., Lovelock, C. E., Krauss, K. W., Hamilton, S. E., Lee, S. Y., Lucas, R., Primavera, J., Rajkaran, A., & Shi, S. (2019). The State of the World's Mangrove Forests: Past, Present, and Future. *Annual Review of Environment and Resources*, *44*(1), 89–115. https://doi.org/10.1146/annurev-environ-101718-033302

GAIN. (2007). Indonesia Fishery Products Shrimp Report 2007. USDA Foreign Agricultural Service. Global Agriculture Information Network. 14pp. Available at: http://apps.fas.usda.gov/gainfiles/200707/146291660.pdf

General guidelines for rearing monodon and vanamei shrimp. Ministerial Regulation Fisheries and Marine No. 75 (2016).

Global Quality and Standards Programme. (2021). *Procedure Operational Cultivation Shrimp Vaname*. Indonesia: Ir. Sukenda.

Global Quality and Standards Programme. (2023). *Procedure Operational Cultivation Simple Pattern Shrimp (Traditional) Plus*. Indonesia: Ir. Sukenda.

Gusmawati, N., Soulard, B., Selmaoui-Folcher, N., Proisy, C., Mustafa, A., Le Gendre, R., ... & Lemonnier, H. (2018). Surveying shrimp aquaculture pond activity using multitemporal VHSR satellite images-case study from the Perancak estuary, Bali, Indonesia. *Marine pollution bulletin*, *131*, 49-60.

Gräslund, S., & Bengtsson, B. E. (2001). Chemicals and biological products used in south-east Asian shrimp farming, and their potential impact on the environment—a review. Science of the Total Environment, 280(1), 93-131.

Guidelines for the use of chemicals in aquaculture and measures to eliminate the use of harmful chemicals. (2013). [Book]. Association of Southeast Asian Nations. http://hdl.handle.net/10862/5880

Hamano, K., Maeno, Y., Klomkling, S., Aue-Umneoy, D. and Tsutsui, I., 2017. Presence of viral pathogens amongst wild Penaeus monodon in Thailand. Japan Agricultural Research Quarterly: JARQ, 51(2), pp.191-197.

Hatfield. (2018, August). Legal & Policy Analysis of Aquaculture Governance in Indonesia. PT Hatfield Indonesia.

Henriksson, P. J. G., Banks, L. K., Suri, S. K., Pratiwi, T. Y., Fatan, N. A., & Troell, M. (2019). Indonesian aquaculture futures—Identifying interventions for reducing environmental impacts. *Environmental Research Letters*, *14*(12), 124062. https://doi.org/10.1088/1748-9326/ab4b79

Hidayati, N. V., Syakti, A. D., Asia, L., Lebarillier, S., Khabouchi, I., Widowati, I., ... & Doumenq, P. (2021). Emerging contaminants detected in aquaculture sites in Java, Indonesia. *Science of The Total Environment*, *773*, 145057.

Holmström, K., Gräslund, S., Wahlström, A., Poungshompoo, S., Bengtsson, B. E., & Kautsky, N. (2003). Antibiotic use in shrimp farming and implications for environmental impacts and human health. International journal of food science & technology, 38(3), 255-266.

Human Rights. Constitution of the Republic of Indonesia. Chapter XA. Article 28H (1945). https://jdih.bapeten.go.id/unggah/dokumen/peraturan/116-full.pdf

Hussain, S. A., & Badola, R. (2010). Valuing mangrove benefits: contribution of mangrove forests to local livelihoods in Bhitarkanika Conservation Area, East Coast of India. *Wetlands Ecology and Management*, *18*, 321-331.

IDH 2018 Investment Guideline for Sustainable Aquaculture in Indonesia (The Sustainable Trade Initiative, Utrecht, The Netherlands) (https://idhsustainabletrade.com/ publication/investment-guideline-for-sustainableaquaculture-in-indonesia-2018/)

Ilman, M., Dargusch, P., Dart, P., & Onrizal. (2016). A historical analysis of the drivers of loss and degradation of Indonesia's mangroves. *Land Use Policy*, *54*, 448–459. https://doi.org/10.1016/j.landusepol.2016.03.010

Ilman, M., Wibisono, I. T. C., & Suryadiputra, I. N. N. (2011). State of the Art Information on Mangrove Ecosystems in Indonesia. Bogor, Indonesia: Wetlands International-Indonesia Programme.

Implementation of spatial planning No.21 (2021).

Implementation of environmental management and protection (2021).

Implementation of environmental management and protection. Appendix I. No. 22 (2021)

Implementation of environmental management and protection. Appendix III. No. 22 (2021)

Implementation of environmental management and protection. Appendix VI. No. 22 (2021)

Implementation of environmental management and protection. Appendix VIII. No. 22 (2021)

Indonesian Act on the Conservation of Biological Resources and Their Ecosystems, Act No. 5 (1990). https://www.ecolex.org/details/legislation/act-on-the-conservation-of-biological-resources-and-their-ecosystems-act-no-5-of-1990-lex-faoc003867/#:~≈:text=environmental%20law-,Act%20on%20the%20conservation%20of%20biological%20resources%20and%20their%20ecos

IUCN (*no date*). https://www.iucnredlist.org/search/stats?landRegions=ID&searchType=species

JALA Shrimp Outlook, 2023. https://jala.tech/outlook/2023#outlook-form

Omnibus Law on Job Creation Act (2020). https://www.fao.org/faolex/results/details/fr/c/LEX-FAOC206548/

Jong, H. N. (2023, July 18). *Indonesia claims record-low deforestation, but accounting raises questions*. Mongabay Environmental News. https://news.mongabay.com/2023/07/indonesia-claims-record-low-deforestation-but-accounting-raises-questions/

Jory, D., & Cabrera, T. (2012). Marine shrimp. Aquaculture: Farming Aquatic Animals and Plants, 476-513.

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

Khiem, N.M., Takahashi, Y., Yasuma, H., Oanh, D.T.H., Hai, T.N., Ut, V.N. and Kimura, N., 2022. Use of GIS and machine learning to predict disease in shrimp farmed on the east coast of the Mekong Delta, Vietnam. Fisheries Science, 88(1), pp.1-13.

Khan and Lively (2020) Khan, M., & Lively, J. A. (2020). Determination of sulfite and antimicrobial residue in imported shrimp to the USA. *Aquaculture Reports*, *18*, 100529.

Kusmarwati, A., Yenni, Y., & Indriati, N. (2017). Resistensi antibiotik pada Vibrio parahaemolyticus dari udang vaname asal pantai utara Jawa untuk pasar ekspor. *Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan*, *12*(2), 91-106.

Leadbitter, D. (2019). Driving change in South East Asian trawl fisheries, fishmeal supply, and aquafeed. *Report to IFFO, The Marine Ingredients Organization and the Global Aquaculture Alliance (GAA)*, *150*.

Lee, D., Yu, Y.B., Choi, J.H., Jo, A.H., Hong, S.M., Kang, J.C. and Kim, J.H., 2022. Viral Shrimp Diseases Listed by the OIE: A Review. Viruses, 14(3), p.585.

Lightner, D.V., 2011. Virus diseases of farmed shrimp in the Western Hemisphere (the Americas): a review. Journal of invertebrate pathology, 106(1), pp.110-130.

List of mandatory environmental impact analysis businesses. Ministerial Regulation Environment and Forestry No.4 (2021).

Luhur, E. S., Deswati, R. H., Apriliani, T., & Arthatiani, F. Y. (2021, October). Driving factors of Indonesian import of fish meal. In *IOP Conference Series: Earth and Environmental Science* (Vol. 860, No. 1, p. 012057). IOP Publishing.

Lusiastuti A, Taukhid, Maskur, Murwantoko, Prayitno S, Sugiani D, Caruso D. 2020. Building and improving the capacity of fish and environmental health management strategy in Indonesia. IOP Conference Series: Earth and Environmental Science. 521. 012016. 10.1088/17551315/521/1/012016

Lymer, D., Funge-Smith, S., Clausen, J., & Miao, W. (2008). Status and potential of fisheries and aquaculture in Asia and the Pacific 2008. RAP Publication (FAO).

Manual of Daignostic Tests for Aquatic Animals. (2021). Chapter 2.2.5. Infection with Infectious Myonecrosis Virus. https://www.woah.org/fileadmin/Home/eng/Health_standards/aahm/current/2.2.05_IMN.pdf

Merican, Z. (2015) Aquaculture Asia Pacific. Volumne 11, Number 1. January/February 2015. pg. 20.

Merican, Z. 2021. A Changing landscape for aquafeed production in Asia. Aqua Culture Asia Pacific Magazine, July/August 2021, p 28-34.

Meyers, T.R. and Hickey, N., 2022. A Perspective: Molecular Detections of new agents in finfish: interpreting biological significance for fish health management. Journal of Aquatic Animal Health. First published: 06 April 2022 https://doi.org/10.1002/aah.10155

Minister of Environment and Forestry of the Republic of Indonesia. (2018). Regulation of the Minister of Environment and Forestry Republic of Indonesia Number P.20/MENLHK/SETJEN/KUM.1/6/2018 About Types of Plants and Animals Protected.

Ministry of Marine Affairs and Fisheries. (2013). Regulation of the Minister of Maritime Affairs and Fisheries Number 26/PERMEN-KP/2013 of 2013 concerning Amendments to Regulation of the Minister of Maritime Affairs and Fisheries Number PER.30/MEN/2012 concerning Capture Fisheries Businesses in the State Fisheries Management Area of the Republic of Indonesia

Ministry of Marine Affairs and Fisheries. (2019). *Development Of Leading Strategic Commodities Of Culture Fishery, And Licensing Governance To Speak Investment.* Presented at the Sustainable Aquaculture Fisheries Development Workshop. September, 2019.

Ministry of Marine Affairs and Fisheries. (2020). Ministry of Marine Affairs and Fisheries Strategic Plan Fisheries Year 2020-2024. Regulation of the Minister of Marine and Fisheries Concerning Amendment to No. 17/MEN-KP (2020).

Ministry of Marine Affairs and Fisheries. (2021). *Cultivation Technology Modern Shrimp and Its Supervisory Management*. Indonesia: Muhammad Yusuf.

Ministry of Marine Affairs and Fisheries. (2021b). National Mangrove Map https://pdasrh.menlhk.go.id/vo/download.php?id=59&token=gWBCAzL6ACrzQ9GlgO35AljlLpXwRdgK

Ministry of Marine Affairs and Fisheries. (2023a). Placement Of Fishing Tools And Auxiliary Equipment Fishing In Measured Fishing Zones And State Fisheries Management Area Of The Republic Of Indonesia In Land Waters. Regulation 36 (2023). https://s3-us-west-2.amazonaws.com/sfw-images/reportsresources/28315/references/-2023permenkp036_1700970893%20(1).pdf

Ministry of Marine Affairs and Fisheries. (2023b). Regulation 11 (2023). https://s3-us-west-2.amazonaws.com/sfw-images/reportsresources/28315/references/Government%20Regulation%20no_%2011%20of%202023%20on%20Measured%20Fishing.pdf

Minapoli. (2021) *Trends and challenges in Indonesia's aquafeed industry. The Fish Site. https://thefishsite.com/articles/trends-and-challenges-in-indonesias-aquafeed-industry*

Miteva, D. A., & Pattanayak, S. K. (2021). The effectiveness of protected areas in the context of decentralization. *World Development*, *142*, 105446.

Muhammad Arif Mulya, Fachriyan Hasmi Pasaribu, Usamah Afiff and Munti Yuhana 2022. Characterization and molecular detection of pathogenicity and antibiotic resistance genes in Vibrio parahaemolyticus isolated from Pacific white shrimp. Jurnal Akuakultur Indonesia. 21, 1 (Jul. 2022), 81-92. DOI: https://doi.org/10.19027/jai.21.1.81-92

Mustafa, A., Ratnawati, E., & Chaidir Undu, M. (2020). Characteristics and management of brackishwater pond soil in South Sulawesi Province, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *564*(1), 012021. https://doi.org/10.1088/1755-1315/564/1/012021

NALO (National Aquaculture Sector Overview). (2006). Indonesia. National Aquaculture Sector Overview Fact Sheets. Text by Sri Paryanti, T. In: FAO Fisheries and Aquaculture Department [online]. Rome. [Cited 24 June 2015]. Available at: http://www.fao.org/fishery/countrysector/nalo_indonesia/en

McNally, C. G., Uchida, E., & Gold, A. J. (2011). The effect of a protected area on the tradeoffs between short-run and long-run benefits from mangrove ecosystems. *Proceedings of the National Academy of Sciences*, *108*(34), 13945-13950.

Napitupulu, L., S. Tanaya, I. Ayostina, I. Andesta, R. Fitriana, D. Ayunda, A. Tussadiah, K. Ervita, K. Makhas, R. Firmansyah, and R. Haryanto. 2022. 'Trends in Marine Resources and Fisheries Management in Indonesia.' Report. Jakarta: World Resources Institute Indonesia. Available online at doi. org/10.46830/wrirpt.20.00064 https://s3-us-west-2.amazonaws.com/sfw-images/reportsresources/28315/references/Marine%20Trends%20Report_WRI%20format_v14.pdf

National Standardization Agency (BSN). (2022). *Determination Sni 8228-1:2022 How To Cultivate Good Fish (CBIB) - Section 1: Shrimp Penaeid As Revis From SNI 82281:2015 How To Bud Ida Yes Fish The Good (CBIB) Ba Gian 1: Shrimp.* Jakarta, Indonesia: National Standardization Agency.

National Standardization Agency (2009). Seed production of vaname shrimp (*Litopenaeus vannamei)* seed class spread SNI 7311:2009.

National Standardization Agency (2006). *Penaeus monodon* tiger prawn seeds (Fabricius, 1798) class of scatter seeds SNI 01-6143-2006.

National Standardization Agency (2006). Seed production of *Penaeus monodon* tiger prawn seeds (Fabricius, 1798) class of scatter seeds SNI 01-6144-2006.

National Standardization Agency (2015). Vannamei shrimp (*Litopenaeus vannamei,* Boone 1931) simple technology plus SNI 8117:2015.

National Standardization Agency (2014). Vannamei shrimp (*Litopenaeus vannamei,* Boone 1931) semi-intensive in lining ponds SNI 8007:2014.

National Standardization Agency (2014). Vannamei shrimp (*Litopenaeus vannamei,* Boone 1931) intensive in lining ponds SNI 8008:2014.

National Standardization Agency (2015). Vannamei shrimp (*Litopenaeus vannamei,* Boone 1931) super-intensive in lining ponds SNI 8118:2015.

National Standardization Agency (2014). Vannamei shrimp (*Litopenaeus vannamei,* Boone 1931) in the pond SNI 8009:2014.

Ngoc, Q. T. K., Xuan, B. B., Sandorf, E. D., Phong, T. N., Trung, L. C., & Hien, T. T. (2021). Willingness to adopt improved shrimp aquaculture practices in Vietnam. Aquaculture Economics & Management, 1–24.

Nguyen, K. A. T., Nguyen, T. A. T., Jolly, C., & Nguelifack, B. M. (2020). Economic Efficiency of Extensive and Intensive Shrimp Production under Conditions of Disease and Natural Disaster Risks in Khánh Hòa and Trà Vinh Provinces, Vietnam. Sustainability, 12(5), 2140. doi:10.3390/su12052140

Novriadi, R., Fadhilah, R., Wahyudi, A. E., & Trullas, C. (2021). Effects of hydrolysable tannins on the growth performance, total haemocyte counts and lysozyme activity of pacific white leg shrimp Litopenaeus vannamei. *Aquaculture Reports*, *21*, 100796.

Novriadi, R., Suwendi, E., & Tan, R. (2022a). The use of corn distiller's dried grains with solubles as a protein source in practical diets for Pacific white leg shrimp Litopenaeus vannamei. *Aquaculture Reports*, *25*, 101209.

Novriadi, R., Herawati, V. E., Prayitno, S. B., Windarto, S., Mertz, K., & Nguyen Duy, H. (2022b). Effect of fermented corn protein concentrate on growth performance, haemocyte counts, histological structure of hepatopancreas and intestinal condition of pacific white shrimp Litopenaeus vannamei. *Aquaculture, Fish and Fisheries*, *2*(2), 82-93.

Novriadi, R., Roigé, O., & Segarra, S. (2022c). Effects of Dietary Nucleotide Supplementation on Performance, Profitability, and Disease Resistance of Litopenaeus vannamei Cultured in Indonesia under Intensive Outdoor Pond Conditions. *Animals*, *12*(16), 2036.

Nur, A. 2007. Analysis of feeds and fertilizers for sustainable aquaculture development in Indonesia. In M.R. Hasan, T. Hecht, S.S. De Silva and A.G.J. Tacon (eds). Study and analysis of feeds and fertilizers for sustainable aquaculture development. FAO Fisheries Technical Paper. No. 497. Rome, FAO. pp. 245–267.

Nurdjana, M. L. (2006, December). Indonesian aquaculture development. InDGA, MMAF. The paper delivered on RCA International Workshop on Innovative Technologies for EcoFriendly Fish Farm Management and Production of Safe Aquaculture Foods, Bali.

Nurhati IS and Murdiyarso D. 2023. National Strategy for Mangrove Ecosystem Management: A reference for the conservation and rehabilitation of coastal areas to achieve Sustainable Development Goals and Low Carbon Development. Working Paper 14. Bogor, Indonesia: CIFOR.

Nurhidayah, L.. (2010). Toward Integrated Coastal Zone Management in Indonesia: Framework Assessment and comparative analysis. Presentation. https://www.un.org/depts/los/nippon/unnff_programme_home/fellows_pages/fellows_papers/nurhidayah_0910_indonesia_PPT.pdf

OECD (2013). OECD review of fisheries: Policies and Summary Statistics 2013, OECD publishing.

OECD. (2018). OECD Review of Fisheries 2017. General Survey of Fisheries Policies. Trade and Agriculture Directorate Fisheries Committee. TAD/FI(2017)14/FINAL.

Orosco, F.L. and Lluisma, A.O., 2017. Prevalence, diversity and co-occurrence of the white spot syndrome virus, monodon baculovirus and Penaeus stylirostris densovirus in wild populations of Penaeus monodon in the Philippines. Diseases of Aquatic Organisms, 125(3), pp.199-206.

Pantjara, B., & Kristanto, A. H. (2020). Pond bottom management and probiotic application in extensive Tiger prawn (Penaeus monodon) culture on acid sulfate soil. *AACL Bioflux*, *13*(2).

Pantjara, B., Sarijanah, A., & Hermawan, M. (2020, June). Improved pond productivity through integrated cultivation of red tilapia (Oreochromis niloticus), tiger shrimp (Penaeus monodon) and seaweed (Gracilaria verrucosa) in Maros, South Sulawesi, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 521, No. 1, p. 012001). IOP Publishing.

Panutrakul, S., Senanan, W., Chavanich, S., Tangkrock-Olan, N., Viyakarn, V., 2010. Ability of Litopenaeus vannamei to survive and compete with local marine shrimp species in the Bangpakong River, Thailand., in: Hoanh, C.T., Szuster, B., Kam, S., Ismail, A., Noble, A. (Eds.), Tropical Deltas and Coastal Zones: Food Production, Communities and Environment at the Land and Water Interface. CABI, Wallingford, pp. 80–92. https://doi.org/10.1079/9781845936181.0080

Perez-Velazquez, M., González-Félix, M.L., Zúñiga-Panduro, M., Barraza-Guardado, R.H., 2010. Evidence of pre-zygotic barriers in attempts to cross-breed Penaeus (Litopenaeus) vannamei (Boone) and P. (Litopenaeus) stylirostris (Stimpson) by means of artificial insemination. Aquaculture 304, 100–103. https://doi.org/10.1016/j.aquaculture.2010.03.021

Poernomo, A. (2004). Technology of probiotics to 78 Effect of different probiotic bacteria on survival rate, growth, and production ..... (Muharijadi Atmomarsono) solve the problems in shrimp pond culture and the culture environment. Paper presented in The National Symposium on Development and Scientific and Technology Innovation in Aquaculture, January 27-29, 2004. Patrajasa Hotel, Semarang, 25 pp.

Pollution prevention, damage prevention, rehabilitation, and improvement of fish resources and their environment. No. 26 (2021).

Pongoh, I. A. A., Dhamayanthi, W., & Iskandar, R. (2021, March). Evaluation of multidimensional sustainability status of vannamei shrimp hatchery in Situbondo regency. In *IOP Conference Series: Earth and Environmental Science* (Vol. 672, No. 1, p. 012035). IOP Publishing.

Protection and Management of the Environment. No. 32 (2009).

Pusparini, W., Cahyana, A., Grantham, H. S., Maxwell, S., Soto-Navarro, C., & Macdonald, D. W. (2023). A bolder conservation future for Indonesia by prioritising biodiversity, carbon and unique ecosystems in Sulawesi. *Scientific Reports*, *13*(1), 842.

Puspasari, R., & Suryandari, A. (2017). Kelimpahan udang putih (Litopenaeus vannamei) di perairan Probolinggo dan Banyuwangi. *Jurnal Penelitian Perikanan Indonesia*, *13*(1), 13-19. http://ejournal-balitbang.kkp.go.id/index.php/jppi/article/view/3772

Raja, U. (2023, February, 20). How shrimp farmers in Indonesia are navigating current challenges. *The Fish Site. https://thefishsite.com/articles/how-shrimp-farmers-in-indonesia-are-navigating-current-challenges*

Rahardian, A., Prasetyo, L. B., Setiawan, Y. U. D. I., & Wikantika, K. E. T. U. T. (2019). Tinjauan historis data dan informasi luas mangrove Indonesia. Media Konservasi, 24(2), 163-178.

Ramdhani, I. (2022, September 6). Indonesian fishermen still use banned destructive fishing nets, despite threat to Ocean. Maritime Fairtrade. https://maritimefairtrade.org/indonesian-fishermen-still-use-banned-destructive-fishing-nets-despite-threat-to-ocean/

Regulation Of The Minister Of Marine And Fisheries Concerning Standards Of Business Activities And Products On The Implementation Of Risk-Based Business Licenses In The Marine And Fishery Sector. No. 10 (2021).

Republic of Indonesia. (2002). Government Regulation Number 15 of 2002 concerning Fish Quarantine. https://faolex.fao.org/docs/pdf/ins52619.pdf

Rico, A., Satapornvanit, K., Haque, M. M., Min, J., Nguyen, P. T., Telfer, T. C., & van den Brink, P. J. (2012). Use of chemicals and biological products in Asian aquaculture and their potential environmental risks: a critical review. Reviews in Aquaculture, 4(2), 75-93.

Rico, A., & Van den Brink, P. J. (2014). Probabilistic risk assessment of veterinary medicines applied to four major aquaculture species produced in Asia. Science of the Total Environment, 468, 630-641.

Royan, M. R. (2020). Integrated Multi-Trophic Aquaculture (IMTA) as a solution for shrimp aquaculture side effects on Northern Coast of Java, Indonesia. *Grouper Jurnal Ilmiah Fakultas Perikanan Universitas Islam Lamongan*, *11*(1), 31-37. https://pdfs.semanticscholar.org/1a67/c20c7432048397dcb1d9fbfed362370a21c8.pdf

Saputra, S. A., & Arfi, F. (2020). Analisis Residu Kloramfenikol pada Udang Windu (Penaeus monodon) Menggunakan High Performance Liquid Cromatography (HPLC). Amina, 1(3), 126-131.

Sari, I. (2015). Understanding the capability of Indonesian shrimp producers to participate in lucrative export markets; using the integrated sustainable livelihoods approach (SLA) and global value chain (GVC) analyses. https://opus.lib.uts.edu.au/handle/10453/39186

Sarjito, S., & Sabdono, A. (2021). Associated Vibrio Species in Shrimp Vibriosis from Traditional Brackish Water Pond in the North Coastal of Central Java, Indonesia. *Genetics of Aquatic Organisms*, *5*(2), 45–54. https://doi.org/10.4194/2459-1831-v5_2_01

Sarjito, M.A., Haditomo, C.A.H. (2016). The Variety of Vibriosis Causative Agent on Vaname Shrimp (Litopenaeus vannamei) and Bacteria Susceptibility to Antibiotics. Journal of Aquaculture Management and Technology. Volume 5 (1), 98-107.

Sarifin, Ir. (2017) *Status of aquaculture feed and feed ingredient production and utilization in Indonesia.* Network of aquaculture centers in Asia-Pacific. https://enaca.org/?id=892

Sasmito, S. D., Basyuni, M., Kridalaksana, A., Saragi-Sasmito, M. F., Lovelock, C. E., & Murdiyarso, D. (2023). Challenges and opportunities for achieving Sustainable Development Goals through restoration of Indonesia’s mangroves. *Nature Ecology & Evolution*, 1-9.

Schar, D., Klein, E. Y., Laxminarayan, R., Gilbert, M., & Van Boeckel, T. P. (2020). Global trends in antimicrobial use in aquaculture. *Scientific reports*, *10*(1), 21878.

Secretariat Satu Data Indonesia. Data One Portal of Industry Statistics. *Accessed October, 2022.* https://data.go.id/

Senanan, W., Panutrakul, S., Barnette, P., Manthachitra, V., Chavanich, S., Kapuscinski, A.R., Tangkrock-Olan, N., Intacharoen, P., Viyakarn, V., Wongwiwatanawute, C., Padetpai, K., 2010. Ecological risk assessment of an alien aquatic species: a case study of Litopenaeus vannamei (Pacific whiteleg shrimp) aquaculture in the Bangpakong River, Thailand, in: Hoanh, C.T., Szuster, B., Kam, S., Ismail, A., Noble, A. (Eds.), Tropical Deltas and Coastal Zones: Food Production, Communities and Environment at the Land and Water Interface. CABI, Wallingford, pp. 64–79. https://doi.org/10.1079/9781845936181.0064

Shrimp Insights. (2020). *SPF L. vannamei Broodstock. Shrimp Insights Report Series*. https://shrimpinsights.com/report-series/vannamei-broodstock

Shrimp Insight. (2022a, June 10). A 2022 Update of the Shrimp Broodstock Market. *Shrimp Insights*. https://shrimpinsights.com/blog/2022-update-shrimp-broodstock-market

Shrimp Insights. (2022b, October 03). *Black will really be back. Big time.* 03 October, 2022. https://www.shrimpinsights.com/blog/black-will-really-be-back-big-time

Siahaan, S., Herman, M. J., & Fitri, N. (2022). Antimicrobial Resistance Situation in Indonesia: A Challenge of Multisector and Global Coordination. Journal of tropical medicine, 2022, 2783300. https://doi.org/10.1155/2022/2783300

Simarmata, R. (2010). Legal complexity in natural resource management in the frontier Mahakam Delta of East Kalimantan, Indonesia. Legal Pluralism & Unofficial L., 1(62), 115–146.

Sivaramakrishnan, T., & Renganathan, R. (2013). Culture practices in a bio-secure shrimp farm in Indonesia. *INFOFISH International*, 27.

Southeast Asian Fisheries Development Center. (2022) The Southeast Asian State of Fisheries and Aquaculture 2022. https://repository.seafdec.org/handle/20.500.12066/6752

Sugama, K., Novita, H., and Koesharyani, I. (2006). Production performance, diseases, SPF breeding and risk issues concerning white shrimp, Penaeus vannamei, introduction into Indonesia. Indonesian Aquaculture Journal. Vol 1 (1). 71pp.

Supriyadi, H., & Rukyani, A. (2000). The use of chemicals in aquaculture in Indonesia. In: J. R. Arthur, C. R. Lavilla-Pitogo, & R. P. Subasinghe (Eds.) Use of Chemicals in Aquaculture in Asia : Proceedings of the Meeting on the Use of Chemicals in Aquaculture in Asia 20-22 May 1996, Tigbauan, Iloilo, Philippines (pp. 113-118). Tigbauan, Iloilo, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center.

Supono, Supono (2021) *Current status of technical and economic analysis of inland shrimp culture in Lampung Province, Indonesia.* AACL Bioflux, 14 (1). pp. 218-226. ISSN 1844-9166

Sumini, S., & Kusdarwati, R. (2020). The discovery of Vibrio harveyi on Litopenaeus vannamei infected white feces disease in Situbondo, East Java. *Jurnal Perikanan Universitas Gadjah Mada*, *22*(1), 9-17.

Sustainable Fisheries Partnership (SFP). Shrimp Indonesia. FishSource profile. In: FishSource [online]. Updated 5 May 2023. Accessed [30 August 2024]. https://www.fishsource.org/aqua_page/4

Tacon, A.G.J. 2002. Thematic Review of Feeds and Feed Management Practices in Shrimp Aquaculture. Report prepared under the World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. Published by the Consortium. 69 pages.

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

Tacon AGJ, M Metian (2008) Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquaculture 285 (1-4): 146-158.

Tan, R., Panakorn, S., Bangarusamy, R., Tran, L., Muhtadi, H. (2020, October 21). *TARS Leading Conversations Webinar (Shrimp Aquaculture: Managing AHPND, EHP and WFS)* [Webinar]. TARS. https://www.youtube.com/watch?v=MO26eCe40O4

Tarunamulia et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 370 012067. https://iopscience.iop.org/article/10.1088/1755-1315/370/1/012067/pdf

Taukhid and Nur'aini, Y. L. (2009). Infectious myonecrosis virus (IMNV) in Pacific white shrimp (Litopenaeus vannamei) in Indonesia (presentation). Aquaculture America 2012. Las Vegas, Nevada, USA. February 29 - March 2, 2012

Taw, Nyan. (2017). A look at various intensive shrimp farming systems in Asia. Global Seafood Alliance. 24 July 2017. https://www.globalseafood.org/advocate/intensive-shrimp-farming-asia/

Technical guidelines for the management of aquaculture areas with an ecosystem approach. No. 154/Per-DJPB (2019).

Technical instructions wastewater treatment for vannamei shrimp. Marine and Fisheries Ministry Directorate General of Cultivation Fisheries (2019).

Technical instructions of product certification scheme Indonesian good aquaculture practices (IndoGap) Part 1: How to share good fish (CPIB) and/or good fish cultivation (CBIB). Appendix IV, 14 (2019).

Technical instructions of product certification scheme Indonesian good aquaculture practices (IndoGap) Good fish cultivation audit checklist (CBIB) Part 1: shrimp (2019).

Tjahjo, D. W. H., Hedianto, D. A., Suryandari, A., Nurfiarini, A., Fahmi, Z., Indriatmoko, I., & Haryadi, J. (2019). Konservasi Sumber Daya Udang Windu (Penaeus monodon) Di Pantai Timur Aceh, Kabupaten Aceh Timur. Jurnal Kebijakan Perikanan Indonesia, 11(1), 39-51.

Susanto, H. (*no date*). Guidelines for traditional monodon shrimp cultivation. Fish Shrimp Windu (Penaeus monodon).

Sustainable Fisheries Partnership (SFP). Shrimp Indonesia. FishSource profile. In: FishSource [online]. Updated 6 April 2021. Accessed [22 February 2023]. https://www.fishsource.org/ama_page/14

Technical guidelines for preventing AHPND, 165 Per-DJPB (2019).

Tortora, Piera and Agnelli, Alberta. (2021) Sustainable Ocean Economy Country Diagnostics of Indonesia. https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DCD(2021)5&docLanguage=En

Tu, V. H., Trang, N. T., Hong, N. B., SON, L. T., DUYEN, C. T. L., & Yabe, M. (2021). Environmental efficiency of Intensive shrimp farming in transforming areas of The Coastal Mekong Delta. J. Fac. Agr., Kyushu Univ., 66(2), 277–289.

Ulate, K., Alfaro-Montoya, J., 2010. Sperm–egg incompatibility in inter-specific inseminations of Penaeus (Litopenaeus) occidentalis, P. (Litopenaeus) stylirostris and P. (Litopenaeus) vannamei. Aquaculture 309, 290–292. https://doi.org/10.1016/j.aquaculture.2010.08.029

United Nations Industrial Development Organization (2020). Project Document for Increasing Trade Capacities of Selected Value Chains within the Fisheries Sector in Indonesia – Extension. https://open.unido.org/api/documents/14791603/download/Signed-Project%20Document%20GQSP%20SMART-Fish%20Indonesia%202019-2022_20190704.pdf

UN World Bank. (2021) Country Summary of Indonesia. Climate Change Knowledge Portal. https://climateknowledgeportal.worldbank.org/country/indonesia/vulnerability

US Food and Drug Administration. (2022) Import Refusals. *Accessed October 2022. https://datadashboard.fda.gov/ora/cd/imprefusals.htm*

Utomo Purusa Tunggul, Romadhoni, Bachtiar, Budijaya, William, Sofwan, Dimaz, Hamzah, Assegaf & Partners. (2021) Environmental Law and Practice in Indonesia: Overview. https://uk.practicallaw.thomsonreuters.com/Document/I135fe76420af11ed9f24ec7b211d8087/View/FullText.html?transitionType=Default&contextData=(sc.Default)&firstPage=true#co_anchor_a716276

Van Der Pijl, W. (2023) *The Global Shrimp Feed Manufacturing Landscape a helicopter view.* Shrimp Insights. https://shrimpinsights.com/report-series/global-shrimp-feed-manufacturing-landscape-helicopter-view

Vo, Q. T., Oppelt, N., Leinenkugel, P., & Kuenzer, C. (2013). Remote sensing in mapping mangrove ecosystems—An object-based approach. *Remote Sensing*, *5*(1), 183-201.

WHO. 2019. Critically important antimicrobials for human medicine, 6th revision.
Geneva: World Health Organization; 2019. Licence: CC BY-NC-SA 3.0 IGO

Wibisana, A. G., & Nuning, W. P. (2018). The implementation of Indonesia's penal sanctions to the increased illegal trade of endangered species. *Law and Justice in a Globalized World*, 195-202.

Wijaya, C. (2020). Indonesia: Thousands protest against'omnibus law'on jobs. *Retrieved from BBC News: https://www.bbc.com/news/world-asia-54460090#product*

Wong, L. L., Chun, L. C., Deris, Z. M., Zainudin, A. A., Ikhwanuddin, M., Iehata, S., … Asaduzzaman, M. (2021). Genetic diversity and population structure of wild and domesticated black tiger shrimp (Penaeus monodon) broodstocks in the Indo-Pacific regions using consolidated mtDNA and microsatellite markers. Gene Reports, 23, 101047. doi:10.1016/j.genrep.2021.101047

World Wildlife Foundation. (2020). *The Study of Black Tiger Shrimp (Penaeus monodon) Broodstock and Its Habitat Characteristics in the Mangrove and Estuary Areas, East Coast of Aceh.*

Xuan, B.B., Sandorf, E.D. and Ngoc, Q.T.K., 2021. Stakeholder perceptions towards sustainable shrimp aquaculture in Vietnam. Journal of Environmental Management, 290, p.112585.

Yasir, I., Tresnati, J., Aprianto, R., Yanti, A., Bestari, A. D., & Tuwo, A. (2021, May). Effect of different doses of saponins and salinity on giant tiger prawn Penaeus monodon and Nile tilapia Oreochromis niloticus. In *IOP Conference Series: Earth and Environmental Science* (Vol. 763, No. 1, p. 012021). IOP Publishing.

Yayasan SustainAqua Indonesia. (2022, February 21). *YSAI AIP Seminar Series Management of Vannamei Shrimp Culture in Facing AHPND Disease.* Sustain Aqua Indonesia. https://sustainaquaindonesia.org/en/2022/02/21/ysai-aip-seminar-series-management-of-vannamei-shrimp-culture-in-facing-ahpnd-disease/

Yayasan SustainAqua Indonesia. (2022, April 26). *Indonesia Shrimp Forum Webinar Series. Sharing Experience in Preventive Action for AHPND/EHP in Intensive Shrimp Culture*. Sustain Aqua Indonesia.

https://sustainaquaindonesia.org/en/2022/04/26/indonesia-shrimp-forum-webinar-series-sharing-experience-in-preventive-action-for-ahpnd-ehp-in-intensive-shrimp-culture/

Yi, D., Reardon, T., Sari, I., Harahap, H., Afry, T., Natawidjaja, R.S., and R. Stringer. (2009). Indonesia's Farmed-Shrimp Value Chains: Key-Informant Study Report. To ACIAR, Final deliverable on Task 2.A (Deliverable 2.A.6) of IFPRI/ACIAR project. December. Available at: http://aciar.gov.au/files/node/14679/appendix_22_ss_supply_chain_study_pdf_30791.pdf

Yi, D., Reardon, T., & Stringer, R. (2018). Shrimp aquaculture technology change in Indonesia: Are small farmers included?. *Aquaculture*, *493*, 436-445.

Zhang, M., Zhao, Y., Shan, B., Liu, Y., Yang, C., Wang, L., ... & Sun, D. (2023). Microsatellite-Marker-Based Evaluation of Stock Enhancement for Kuruma Prawn Pernaeus japonicus in Beibu Gulf, South China Sea. *Fishes*, *8*(12), 568. https://www.mdpi.com/2410-3888/8/12/568

Zwart, M.P., Dieu, B.T.M., Hemerik, L. and Vlak, J.M., 2010. Evolutionary trajectory of white spot syndrome virus (WSSV) genome shrinkage during spread in Asia. PLoS One, 5(10), p.e13400.

Appendix 1 - Data points and all scoring calculations

L. vannamei, Intensive Production System Scores

Criterion 1: Data	
Data Category	**Data Quality**
Production	5.0
Management	5.0
Effluent	5.0
Habitat	5.0
Chemical Use	2.5
Feed	5.0
Escapes	2.5
Disease	2.5
Source of stock	10.0
Wildlife mortalities	2.5
Escape of secondary species	5.0
C1 Data Final Score (0-10)	**4.545**
	Yellow

Shrimp

Criterion 2: Effluent	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0-10)	**5**
Critical?	NO

Select the species or "System" from the list Shrimp

Only select "System" if C2 was done as a multi-species risk-based assessment.

Criterion 2 - Effluent Risk-based assessment	
2.1a Biological waste production	**Data and Scores**
Protein content of feed (%)	33.600
eFCR	1.400
Fertilizer N input (kg N/ton fish)	0.600
Protein content of harvested fish (%)	17.800
N content factor (fixed)	0.160
N input per ton of fish produced (kg)	75.864
N output in each ton of fish harvested (kg)	28.480
Waste N produced per ton of fish (kg)	47.384

2.1b Production System discharge	**Data and Scores**
Basic production system score	0.510
Adjustment 1 (if applicable)	-0.240
Adjustment 2 (if applicable)	0.000
Adjustment 3 (if applicable)	0.000
Boundary adjustment (if applicable)	0.000
Discharge (Factor 2.1b) score (0-1)	0.270
Waste discharged per ton of production (kg N ton-1)	12.794
Waste discharge score (0-10)	8.000

2.2 Management of farm-level and cumulative effluent impacts	
2.2a Content of effluent management measure	3
2.2b Enforcement of effluent management measures	2
2.2 Effluent management effectiveness	2.400
C2 Effluent Final Score (0-10)	**6**
Critical?	No

C3 applies to all species

Criterion 3: Habitat	
F3.1. Habitat conversion and function	**Data and Scores**
F3.1 Score (0-10)	4
F3.2 – Management of farm-level and cumulative habitat impacts	
3.2a Content of habitat management measure	2
3.2b Enforcement of habitat management measures	1
3.2 Habitat management effectiveness	0.800
C3 Habitat Final Score (0-10)	**2.933**
Critical?	No

For C4, copy either the single species table or the all-species "system" table below

Single species

Criterion 4: Chemical Use	
Single species assessment	Data and Scores
Chemical use initial score (0-10)	3.0
Trend adjustment	0.0
C4 Chemical Use Final Score (0-10)	**3.0**
Critical?	No

Shrimp

Criterion 4: Chemical Use	
All-species assessment	**Data and Scores**
Chemical use initial score (0-10)	3
Trend adjustment	0
C4 Chemical Use Final Score (0-10)	**3**
Critical?	No

Select the species or "System" again from the list Shrimp

Only select "System" if the C5 Feed Assessment was done as a multi-species system.

Criterion 5: Feed	
5.1 Wild Fish Use	
5.1a Forage Fish Efficiency Ratio (FFER)	**Data and Scores**
Fishmeal from whole fish, weighted inclusion level %	4.700
Fishmeal from byproducts, weighted inclusion %	7.900
Byproduct fishmeal inclusion (@ 5%)	0.395
Fishmeal yield value, weighted %	22.500
Fish oil from whole fish, weighted inclusion level %	0.000
Fish oil from byproducts, weighted inclusion %	2.500
Byproduct fish oil inclusion (@ 5%)	0.125
Fish oil yield value, weighted %	5.000
eFCR	1.400
FFER Fishmeal value	**0.317**
FFER Fish oil value	**0.035**
Critical (FFER >4)?	No

5.1b Sustainability of Source fisheries	**Data and Scores**
Source fishery sustainability score	5.534
Critical Source fisheries?	No
SFW "Red" Source fisheries?	No
FFER for red-rated fisheries	n/a
Critical (SFW Red and FFER >=1)?	No
Final Factor 5.1 Score	**7.400**

5.2 Net Protein Gain or Loss (%)	**Data and Scores**
Weighted total feed protein content	33.600
Protein INPUT kg/100kg harvest	47.040
Whole body harvested fish protein content	17.800
Net protein gain or loss	-62.160
Species-specific Factor 5.2 score	**3**
Critical (Score = 0)?	No
Critical (FFER>3 and 5.2 score <2)?	No

5.3 Feed Footprint	**Data and Scores**
GWP (kg CO2-eq kg-1 farmed seafood protein)	**14.343**
Contribution (%) from fishmeal from whole fish	2.454
Contribution (%) from fish oil from whole fish	0.000
Contribution (%) from fishmeal from byproducts	5.204
Contribution (%) from fish oil from byproducts	1.060
Contribution (%) from crop ingredients	87.793
Contribution (%) from land animal ingredients	3.364
Contribution (%) from other ingredients	0.125
Factor 5.3 score	**6**
C5 Final Feed Criterion Score	**6.0**
Critical?	**No**

Select species again	Shrimp

Criterion 6: Escapes	**Data and Scores**
F6.1 System escape risk	3
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	3.000
F6.2 Invasiveness score	6
C6 Escape Final Score (0-10)	**4.0**
Critical?	No

Shrimp

Criterion 7: Disease	**Data and Scores**
Evidence-based or Risk-based assessment	Risk
Final C7 Disease Criterion score (0-10)	**4**
Critical?	No

Shrimp

Criterion 8X Source of Stock	**Data and Scores**
Percent of production dependent on wild sources (%)	0.0
Initial Source of Stock score (0-10)	0.0
Use of ETP or SFW "Red" fishery sources	No
Lowest score if multiple species farmed (0-10)	n/a
C8X Source of stock Final Score (0-10)	**0**
Critical?	No

	Shrimp

Criterion 9X Wildlife Mortality parameters	**Data and Scores**
Single species wildlife mortality score	-6
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**-6**
Critical?	No

	Shrimp

Criterion 10X: Introduction of Secondary Species	**Data and Scores**
Production reliant on transwaterbody movements (%)	100
Factor 10Xa score	0
Biosecurity of the source of movements (0-10)	10
Biosecurity of the farm destination of movements (0-10)	4
Species-specific score 10X score	0.000
Multi-species assessment score if applicable	n/a
C10X Introduction of Secondary Species Final Score	**0.000**
Critical?	n/a

L. vannamei, Semi-intensive Production System Scores

Criterion 1: Data	
Data Category	**Data Quality**
Production	5.0
Management	5.0
Effluent	5.0
Habitat	5.0
Chemical Use	2.5
Feed	5.0
Escapes	2.5
Disease	2.5
Source of stock	10.0
Wildlife mortalities	2.5
Escape of secondary species	5.0
C1 Data Final Score (0-10)	**4.545**
	Yellow

Shrimp

Criterion 2: Effluent	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0-10)	**5**
Critical?	NO

Select the species or "System" from the list Shrimp

Only select "System" if C2 was done as a multi-species risk-based assessment.

Criterion 2 - Effluent Risk-based assessment	
2.1a Biological waste production	**Data and Scores**
Protein content of feed (%)	33.600
eFCR	1.400
Fertilizer N input (kg N/ton fish)	2.580
Protein content of harvested fish (%)	17.800
N content factor (fixed)	0.160
N input per ton of fish produced (kg)	77.844
N output in each ton of fish harvested (kg)	28.480
Waste N produced per ton of fish (kg)	49.364

2.1b Production System discharge	Data and Scores
Basic production system score	0.510
Adjustment 1 (if applicable)	-0.240
Adjustment 2 (if applicable)	0.000
Adjustment 3 (if applicable)	0.000
Boundary adjustment (if applicable)	0.000
Discharge (Factor 2.1b) score (0-1)	0.270
Waste discharged per ton of production (kg N ton-1)	13.328
Waste discharge score (0-10)	8.000

2.2 Management of farm-level and cumulative effluent impacts	
2.2a Content of effluent management measure	3
2.2b Enforcement of effluent management measures	2
2.2 Effluent management effectiveness	2.400
C2 Effluent Final Score (0-10)	**6**
Critical?	No

C3 applies to all species

Criterion 3: Habitat	
F3.1. Habitat conversion and function	**Data and Scores**
F3.1 Score (0-10)	4
F3.2 – Management of farm-level and cumulative habitat impacts	
3.2a Content of habitat management measure	2
3.2b Enforcement of habitat management measures	1
3.2 Habitat management effectiveness	0.800
C3 Habitat Final Score (0-10)	**2.933**
Critical?	No

For C4, copy either the single species table or the all-species "system" table below

Single species

Criterion 4: Chemical Use	
Single species assessment	Data and Scores
Chemical use initial score (0-10)	3.0
Trend adjustment	0.0
C4 Chemical Use Final Score (0-10)	**3.0**
Critical?	No

Shrimp

Criterion 4: Chemical Use	
All-species assessment	**Data and Scores**
Chemical use initial score (0-10)	3
Trend adjustment	0
C4 Chemical Use Final Score (0-10)	**3**
Critical?	No

Select the species or "System" again from the list Shrimp

Only select "System" if the C5 Feed Assessment was done as a multi-species system.

Criterion 5: Feed	
5.1 Wild Fish Use	
5.1a Forage Fish Efficiency Ratio (FFER)	**Data and Scores**
Fishmeal from whole fish, weighted inclusion level %	4.700
Fishmeal from byproducts, weighted inclusion %	7.900
Byproduct fishmeal inclusion (@ 5%)	0.395
Fishmeal yield value, weighted %	22.500
Fish oil from whole fish, weighted inclusion level %	0.000
Fish oil from byproducts, weighted inclusion %	2.500
Byproduct fish oil inclusion (@ 5%)	0.125
Fish oil yield value, weighted %	5.000
eFCR	1.400
FFER Fishmeal value	**0.317**
FFER Fish oil value	**0.035**
Critical (FFER >4)?	No

5.1b Sustainability of Source fisheries	**Data and Scores**
Source fishery sustainability score	5.534
Critical Source fisheries?	No
SFW "Red" Source fisheries?	No
FFER for red-rated fisheries	n/a
Critical (SFW Red and FFER >=1)?	No
Final Factor 5.1 Score	**7.400**

5.2 Net Protein Gain or Loss (%)	**Data and Scores**
Weighted total feed protein content	33.600
Protein INPUT kg/100kg harvest	47.040
Whole body harvested fish protein content	17.800
Net protein gain or loss	-62.160
Species-specific Factor 5.2 score	**3**
Critical (Score = 0)?	No
Critical (FFER>3 and 5.2 score <2)?	No

5.3 Feed Footprint	**Data and Scores**
GWP (kg CO2-eq kg-1 farmed seafood protein)	**14.343**
Contribution (%) from fishmeal from whole fish	2.454
Contribution (%) from fish oil from whole fish	0.000
Contribution (%) from fishmeal from byproducts	5.204
Contribution (%) from fish oil from byproducts	1.060
Contribution (%) from crop ingredients	87.793
Contribution (%) from land animal ingredients	3.364
Contribution (%) from other ingredients	0.125
Factor 5.3 score	**6**
C5 Final Feed Criterion Score	**6.0**
Critical?	**No**

Select species again	Shrimp

Criterion 6: Escapes	**Data and Scores**
F6.1 System escape risk	3
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	3.000
F6.2 Invasiveness score	6
C6 Escape Final Score (0-10)	**4.0**
Critical?	No

Shrimp

Criterion 7: Disease	**Data and Scores**
Evidence-based or Risk-based assessment	Risk
Final C7 Disease Criterion score (0-10)	**4**
Critical?	No

Shrimp

Criterion 8X Source of Stock	**Data and Scores**
Percent of production dependent on wild sources (%)	0.0
Initial Source of Stock score (0-10)	0.0
Use of ETP or SFW "Red" fishery sources	No
Lowest score if multiple species farmed (0-10)	n/a
C8X Source of stock Final Score (0-10)	**0**
Critical?	No

Shrimp

Criterion 9X Wildlife Mortality parameters	**Data and Scores**
Single species wildlife mortality score	-6
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**-6**
Critical?	No

Shrimp

Criterion 10X: Introduction of Secondary Species	**Data and Scores**
Production reliant on transwaterbody movements (%)	100
Factor 10Xa score	0
Biosecurity of the source of movements (0-10)	10
Biosecurity of the farm destination of movements (0-10)	4
Species-specific score 10X score	0.000
Multi-species assessment score if applicable	n/a
C10X Introduction of Secondary Species Final Score	**0.000**
Critical?	n/a

L. vannamei, **Extensive Production System Scores**

Criterion 1: Data	
Data Category	**Data Quality**
Production	5.0
Management	5.0
Effluent	5.0
Habitat	5.0
Chemical Use	2.5
Feed	5.0
Escapes	2.5
Disease	2.5
Source of stock	10.0
Wildlife mortalities	2.5
Escape of secondary species	5.0
C1 Data Final Score (0-10)	**4.545**
	Yellow

Shrimp

Criterion 2: Effluent	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0-10)	**5**
Critical?	NO

Select the species or "System" from the list Shrimp

Only select "System" if C2 was done as a multi-species risk-based assessment.

Criterion 2 - Effluent Risk-based assessment	
2.1a Biological waste production	**Data and Scores**
Protein content of feed (%)	0.000
eFCR	0.000
Fertilizer N input (kg N/ton fish)	70.190
Protein content of harvested fish (%)	17.800
N content factor (fixed)	0.160
N input per ton of fish produced (kg)	70.190
N output in each ton of fish harvested (kg)	28.480
Waste N produced per ton of fish (kg)	41.710

2.1b Production System discharge	**Data and Scores**
Basic production system score	0.510
Adjustment 1 (if applicable)	-0.240
Adjustment 2 (if applicable)	0.000
Adjustment 3 (if applicable)	0.000
Boundary adjustment (if applicable)	0.000
Discharge (Factor 2.1b) score (0-1)	0.270
Waste discharged per ton of production (kg N ton-1)	11.262
Waste discharge score (0-10)	8.000

2.2 Management of farm-level and cumulative effluent impacts	
2.2a Content of effluent management measure	3
2.2b Enforcement of effluent management measures	2
2.2 Effluent management effectiveness	2.400
C2 Effluent Final Score (0-10)	**6**
Critical?	No

C3 applies to all species

Criterion 3: Habitat	
F3.1. Habitat conversion and function	**Data and Scores**
F3.1 Score (0-10)	4
F3.2 – Management of farm-level and cumulative habitat impacts	
3.2a Content of habitat management measure	2
3.2b Enforcement of habitat management measures	1
3.2 Habitat management effectiveness	0.800
C3 Habitat Final Score (0-10)	**2.933**
Critical?	No

For C4, copy either the single species table or the all-species "system" table below

Single species

Criterion 4: Chemical Use	
Single species assessment	Data and Scores
Chemical use initial score (0-10)	6.0
Trend adjustment	0.0
C4 Chemical Use Final Score (0-10)	**6.0**
Critical?	No

Shrimp

Criterion 4: Chemical Use	
All-species assessment	**Data and Scores**
Chemical use initial score (0-10)	6
Trend adjustment	0
C4 Chemical Use Final Score (0-10)	**6**
Critical?	No

Select the species or "System" again from the list	Shrimp

Only select "System" if the C5 Feed Assessment was done as a multi-species system.

Criterion 5: Feed	
5.1 Wild Fish Use	
5.1a Forage Fish Efficiency Ratio (FFER)	**Data and Scores**
Fishmeal from whole fish, weighted inclusion level %	0.000
Fishmeal from byproducts, weighted inclusion %	0.000
Byproduct fishmeal inclusion (@ 5%)	0.000
Fishmeal yield value, weighted %	0.000
Fish oil from whole fish, weighted inclusion level %	0.000
Fish oil from byproducts, weighted inclusion %	0.000
Byproduct fish oil inclusion (@ 5%)	0.000
Fish oil yield value, weighted %	0.000
eFCR	0.000
FFER Fishmeal value	**Unfed**
FFER Fish oil value	**Unfed**
Critical (FFER >4)?	No

5.1b Sustainability of Source fisheries	**Data and Scores**
Source fishery sustainability score	Unfed
Critical Source fisheries?	No
SFW "Red" Source fisheries?	No
FFER for red-rated fisheries	n/a
Critical (SFW Red and FFER >=1)?	No
Final Factor 5.1 Score	**10.000**

5.2 Net Protein Gain or Loss (%)	**Data and Scores**
Weighted total feed protein content	0.000
Protein INPUT kg/100kg harvest	0.000
Whole body harvested fish protein content	17.800
Net protein gain or loss	Unfed
Species-specific Factor 5.2 score	**10**
Critical (Score = 0)?	No
Critical (FFER>3 and 5.2 score <2)?	No

5.3 Feed Footprint	Data and Scores
GWP (kg CO2-eq kg-1 farmed seafood protein)	**0.000**
Contribution (%) from fishmeal from whole fish	#DIV/0!
Contribution (%) from fish oil from whole fish	#DIV/0!
Contribution (%) from fishmeal from byproducts	#DIV/0!
Contribution (%) from fish oil from byproducts	#DIV/0!
Contribution (%) from crop ingredients	#DIV/0!
Contribution (%) from land animal ingredients	#DIV/0!
Contribution (%) from other ingredients	#DIV/0!
Factor 5.3 score	**10**
C5 Final Feed Criterion Score	**10.0**
Critical?	**No**

Select species again	Shrimp

Criterion 6: Escapes	Data and Scores
F6.1 System escape risk	1
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	1.000
F6.2 Invasiveness score	6
C6 Escape Final Score (0-10)	**3.0**
Critical?	No

Shrimp

Criterion 7: Disease	Data and Scores
Evidence-based or Risk-based assessment	Risk
Final C7 Disease Criterion score (0-10)	**6**
Critical?	No

Shrimp

Criterion 8X Source of Stock	Data and Scores
Percent of production dependent on wild sources (%)	0.0
Initial Source of Stock score (0-10)	0.0
Use of ETP or SFW "Red" fishery sources	No
Lowest score if multiple species farmed (0-10)	n/a
C8X Source of stock Final Score (0-10)	**0**
Critical?	No

Shrimp

Criterion 9X Wildlife Mortality parameters	Data and Scores
Single species wildlife mortality score	-6
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**-6**
Critical?	No

Shrimp

Criterion 10X: Introduction of Secondary Species	Data and Scores
Production reliant on transwaterbody movements (%)	100
Factor 10Xa score	0
Biosecurity of the source of movements (0-10)	10
Biosecurity of the farm destination of movements (0-10)	4
Species-specific score 10X score	0.000
Multi-species assessment score if applicable	n/a
C10X Introduction of Secondary Species Final Score	**0.000**
Critical?	n/a

P. monodon, **Extensive Production System Scores**

Criterion 1: Data	
Data Category	**Data Quality**
Production	5.0
Management	5.0
Effluent	5.0
Habitat	5.0
Chemical Use	2.5
Feed	5.0
Escapes	2.5
Disease	2.5
Source of stock	5.0
Wildlife mortalities	2.5
Escape of secondary species	5.0
C1 Data Final Score (0-10)	**4.091**
	Yellow

Shrimp

Criterion 2: Effluent	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0-10)	**5**
Critical?	NO

Select the species or "System" from the list Shrimp

Only select "System" if C2 was done as a multi-species risk-based assessment.

Criterion 2 - Effluent Risk-based assessment	
2.1a Biological waste production	**Data and Scores**
Protein content of feed (%)	0.000
eFCR	0.000
Fertilizer N input (kg N/ton fish)	70.190
Protein content of harvested fish (%)	18.900
N content factor (fixed)	0.160
N input per ton of fish produced (kg)	70.190
N output in each ton of fish harvested (kg)	30.240
Waste N produced per ton of fish (kg)	39.950

2.1b Production System discharge	**Data and Scores**
Basic production system score	0.510
Adjustment 1 (if applicable)	-0.240
Adjustment 2 (if applicable)	0.000
Adjustment 3 (if applicable)	0.000
Boundary adjustment (if applicable)	0.000
Discharge (Factor 2.1b) score (0-1)	0.270
Waste discharged per ton of production (kg N ton-1)	10.787
Waste discharge score (0-10)	8.000

2.2 Management of farm-level and cumulative effluent impacts	
2.2a Content of effluent management measure	3
2.2b Enforcement of effluent management measures	2
2.2 Effluent management effectiveness	2.400
C2 Effluent Final Score (0-10)	**6**
Critical?	No

C3 applies to all species

Criterion 3: Habitat	
F3.1. Habitat conversion and function	**Data and Scores**
F3.1 Score (0-10)	3
F3.2 – Management of farm-level and cumulative habitat impacts	
3.2a Content of habitat management measure	2
3.2b Enforcement of habitat management measures	1
3.2 Habitat management effectiveness	0.800
C3 Habitat Final Score (0-10)	**2.267**
Critical?	No

For C4, copy either the single species table or the all-species "system" table below

Single species

Criterion 4: Chemical Use	
Single species assessment	Data and Scores
Chemical use initial score (0-10)	6.0
Trend adjustment	0.0
C4 Chemical Use Final Score (0-10)	**6.0**
Critical?	No

Shrimp

Criterion 4: Chemical Use	
All-species assessment	**Data and Scores**
Chemical use initial score (0-10)	6
Trend adjustment	0
C4 Chemical Use Final Score (0-10)	**6**
Critical?	No

Select the species or "System" again from the list	Shrimp

Only select "System" if the C5 Feed Assessment was done as a multi-species system.

Criterion 5: Feed	
5.1 Wild Fish Use	
5.1a Forage Fish Efficiency Ratio (FFER)	**Data and Scores**
Fishmeal from whole fish, weighted inclusion level %	0.000
Fishmeal from byproducts, weighted inclusion %	0.000
Byproduct fishmeal inclusion (@ 5%)	0.000
Fishmeal yield value, weighted %	0.000
Fish oil from whole fish, weighted inclusion level %	0.000
Fish oil from byproducts, weighted inclusion %	0.000
Byproduct fish oil inclusion (@ 5%)	0.000
Fish oil yield value, weighted %	0.000
eFCR	0.000
FFER Fishmeal value	**Unfed**
FFER Fish oil value	**Unfed**
Critical (FFER >4)?	No

5.1b Sustainability of Source fisheries	**Data and Scores**
Source fishery sustainability score	Unfed
Critical Source fisheries?	No
SFW "Red" Source fisheries?	No
FFER for red-rated fisheries	n/a
Critical (SFW Red and FFER >=1)?	No
Final Factor 5.1 Score	**10.000**

5.2 Net Protein Gain or Loss (%)	**Data and Scores**
Weighted total feed protein content	0.000
Protein INPUT kg/100kg harvest	0.000
Whole body harvested fish protein content	18.900
Net protein gain or loss	Unfed
Species-specific Factor 5.2 score	**10**
Critical (Score = 0)?	No
Critical (FFER>3 and 5.2 score <2)?	No

5.3 Feed Footprint	Data and Scores
GWP (kg CO2-eq kg-1 farmed seafood protein)	**0.000**
Contribution (%) from fishmeal from whole fish	#DIV/0!
Contribution (%) from fish oil from whole fish	#DIV/0!
Contribution (%) from fishmeal from byproducts	#DIV/0!
Contribution (%) from fish oil from byproducts	#DIV/0!
Contribution (%) from crop ingredients	#DIV/0!
Contribution (%) from land animal ingredients	#DIV/0!
Contribution (%) from other ingredients	#DIV/0!
Factor 5.3 score	**10**
C5 Final Feed Criterion Score	**10.0**
Critical?	**No**

Select species again Shrimp

Criterion 6: Escapes	Data and Scores
F6.1 System escape risk	1
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	1.000
F6.2 Invasiveness score	8
C6 Escape Final Score (0-10)	**4.0**
Critical?	No

Shrimp

Criterion 7: Disease	Data and Scores
Evidence-based or Risk-based assessment	Risk
Final C7 Disease Criterion score (0-10)	**6**
Critical?	No

Shrimp

Criterion 8X Source of Stock	Data and Scores
Percent of production dependent on wild sources (%)	100.0
Initial Source of Stock score (0-10)	-10.0
Use of ETP or SFW "Red" fishery sources	No
Lowest score if multiple species farmed (0-10)	n/a
C8X Source of stock Final Score (0-10)	**-10**
Critical?	No

	Shrimp
Criterion 9X Wildlife Mortality parameters	**Data and Scores**
Single species wildlife mortality score	-6
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**-6**
Critical?	No

	Shrimp
Criterion 10X: Introduction of Secondary Species	**Data and Scores**
Production reliant on transwaterbody movements (%)	86
Factor 10Xa score	1
Biosecurity of the source of movements (0-10)	1
Biosecurity of the farm destination of movements (0-10)	8
Species-specific score 10X score	-1.800
Multi-species assessment score if applicable	n/a
C10X Introduction of Secondary Species Final Score	**-1.800**
Critical?	n/a