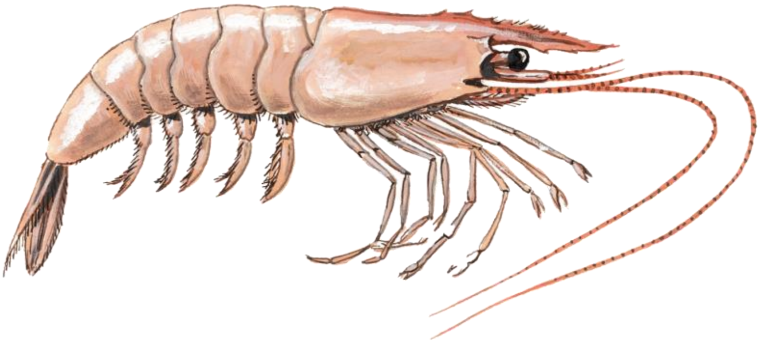
Monterey Bay Aquarium
Seafood Watch

Environmental sustainability assessment of farmed whiteleg shrimp from Ecuador produced in semi-intensive ponds



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Species:	Whiteleg shrimp (*Litopenaeus vannamei*)
Location:	Ecuador
Gear:	Semi-intensive ponds
Type:	Farmed
Author:	Seafood Watch
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Assessed using Seafood Watch Aquaculture Standard v4

About Seafood Watch®

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

Each sustainability recommendation on the regional pocket guides is supported by a Seafood 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 recommendation of "Best Choices," "Good Alternatives" or "Avoid." 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 recommendations 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. byproducts 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.

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[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 recommendation is developed on additional evaluation guidelines. Criteria ratings and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

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

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

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

Final Seafood Recommendation

Whiteleg shrimp
Litopenaeus vannamei
Ecuador
Semi intensive ponds

Criterion	Score	Rank	Critical?
C1 Data	5.23	Yellow	
C2 Effluent	5.00	Yellow	NO
C3 Habitat	3.47	Yellow	NO
C4 Chemicals	3.00	Red	NO
C5 Feed	5.45	Yellow	NO
C6 Escapes	4.00	Yellow	NO
C7 Disease	4.00	Yellow	NO
C8X Source	0.00	Green	NO
C9X Wildlife mortalities	-2.00	Green	NO
C10X Introduced species escape	0.00	Green	
Total	**28.144**		
Final score (0-10)	**4.021**		

OVERALL RANKING

Final Score	4.02
Initial rank	Yellow
Red criteria	1
Interim rank	Yellow
Critical Criteria?	NO

FINAL RANK
Yellow

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

Summary

The final numerical score for whiteleg shrimp (*L. vannamei)* produced in semi-intensive ponds in Ecuador is 4.02 out of 10, which is in the Yellow range. With one Red criteria (Chemicals), the final rank is Yellow and a “Good Alternative” recommendation.

Executive Summary

Currently, the majority of Ecuadorian farmed whiteleg shrimp, *Litopenaeus vannamei*, are grown in semi-intensive pond systems characterized with 8% daily water exchange. There are some farms that qualify as semi-extensive production systems, but the volume of production and how much is destined for export markets is unknown. For the purpose of this report, semi-intensive production systems and an average daily water exchange of 8% is considered representative of the Ecuadorian shrimp industry.

After export production reached a 30 year low in the year 2000, the industry has increased exports by an average of 16% per year (CNA, 2019). Export volume in 2019 was expected to reach record highs with estimates ranging between 510,000 to 515,000 metric tons (mt) – a 10% increase from 2018 (Evans, 2019). However, according to the National Chamber of Aquaculture, exports for 2019 were actually 633,000 mt, a 25% increase from 2018. Ecuador's top 10 export markets by volume for shrimp in 2019 include (ranked in order of mt): China, United States, Vietnam, Spain, France, Italy, South Korea, Russia, Colombia, and England. Combined, these countries represent approximately 95% of Ecuadorian shrimp exports (CNA, 2019). In 2018, Ecuador was the 3rd largest supplier of shrimp to the U.S. markets behind India and Indonesia (NMFS, 2019).

There are about 3,933 registered shrimp farms in Ecuador currently operating on 216,610.91 hectares (Subsecretary of Aquaculture, 2020). The industry also includes 18 feed mills, 20 broodstock facilities, 180 hatcheries, and about 80 processing plants (Piedrahita, 2018a). Four large vertically integrated shrimp companies in Ecuador – Santa Priscila, Expalsa, Omarsa, and SONGA – combine to produce 42% of Ecuador's total shrimp exports (Seafood TIP, 2019).

The availability and quality of data of the shrimp farming industry in Ecuador is moderate. There are some transparency, organizational, and accessibility issues with data availability. Once data were obtained, the quality of data were considered moderate as gaps in the enforcement of regulations and farms ability to meet prescriptive thresholds were not well detailed. These characteristics are consistent with the Effluent, Habitat, Chemical Use, Feed, Escapes, and Disease Criteria and the Management Data category. Of the information obtained, there was moderate confidence in its ability to provide useful insight of the industry altogether and the final score for Criterion 1 – Data is 5.23 out of 10.

The amount of waste discharged from shrimp farms can be highly variable and dependent on multiple farm practices including feeding rates, water exchange, use of settling ponds or other treatment at exchange or harvest, and sludge disposal. Similarly, the impacts of those waste discharges can be highly variable depending on the characteristics of the receiving waterbody. As effluent data quality and availability is moderate/low (i.e. Criterion 1 score of 5 of 10 or lower for the effluent category), the Seafood Watch Risk-Based Assessment was utilized. Production systems for Ecuadorian whiteleg shrimp are semi-intensive ponds utilizing a feed protein content 31.7%, an eFCR of 1.55, and fertilizer input of 0.93 kg of nitrogen per ton of shrimp produced. This results in a net discharge 51.06 kg of nitrogen per mt of shrimp. The daily water exchange rate for Ecuadorian shrimp ponds is 8%, and ponds release approximately 51% of the waste produced by shrimp. As a result, 26.04 kg N per mt of shrimp produced is discharged from the farm. Factor 2.1a and Factor 2.1b combine to result in a final Factor 2.1 score of 7 out of 10. The discharge of effluent to the surrounding water bodies is managed by Ecuador's Ministry of Environment. Effluent limits are assigned at the site level with some consideration of the ecological carrying capacity of the receiving water bodies. As a result, the score for Factor 2.2a is considered moderate and a 3 out of 5. The enforcement of effluent limits is moderate. Agencies and regulations are identifiable, contactable, and measurable, but the transparency, and frequency of monitoring and onsite inspections creates gaps in compliance to effluent standards. Therefore, the score for Factor 2.2b is 3 out of 5. The final score for Factor 2.2 is a combination of Factor 2.2a (3 out of 5) and Factor 2.2b (3 out of 5), and results in a final score of 3.6 out of 10. Factors 2.1 and 2.2 combined result in a final score of 5 out of 10 for Criterion 2 – Effluent.

Significant conversion of estuary habitat to shrimp farms occurred prior to 1999 in Ecuador as mangroves and estuaries were the preferred location for shrimp farm development. Since 1999, new development of dry shrub habitat, highlands, along the estuary edge is ongoing. In total, the shrimp farming industry has increased by 41,357.39 ha since 1999 with all expansion occurring outside of the estuary along the estuary edge. Over the past 3 years, 6,334.98 ha of habitat along the estuary edge has been converted to shrimp farming area. Considering that the estuary and the estuary edge (dry shrub habitat) are fundamentally connected habitats, the significant expansion of shrimp farms into the estuary edge since 1999 has extended the impacts of the shrimp farming industry from within the estuary to the estuary edge. Therefore, considering the historic loss of functionality in the broader estuarine ecosystem, recent marginal conversion on the estuary edge is not considered to represent ongoing loss of functionality in the estuary and the final score is 4 out of 10. The management system does require most farms to be sited according to ecological principles and/or environmental considerations, but there are limited considerations of cumulative habitat impacts and loss of ecosystem services. As a result, the final score for Factor 3.2a is 2 out of 5. These management measures are enforced by organizations that are identifiable and contactable. The size and scale of these agencies and co-management groups are not well understood, so it is challenging to determine whether they are able to effectively manage the environmental regulations and habitat measures outlined. About 31% of shrimp farms are considered low impact and are operating in the highlands, where all new development has occurred since 1999. Low impact farms are not as rigorously vetted prior to aquaculture production as medium and high impact farms, which are required to be sited with EMP and EIA. As a result, there are limitations that reduce the effectiveness of habitat enforcement. Therefore, the score for Factor 3.2b is 3 out of 5. The score for Criterion 3 – Habitat is a combination of the scores for Factor 3.1 – Habitat conversion and function (4 out of 10) and Factor 3.2 – Farm siting regulation and management (2.40 out of 10), and the final score is 3.47 out of 10.

Overall, chemical use in Ecuadorian shrimp aquaculture is common, though most do not pose significant environmental concerns. The chemicals used for pond preparation in Ecuadorian shrimp farming pose a low risk to the environment, given the rapid degradation of these compounds and their byproducts. On the other hand, the use of antibiotics in aquaculture can result in the development of antibiotic-resistant bacteria in the environment and pose significant risks to both the environment and human health. There are effective regulations that limit the type of antibiotics available and its use is enforced, so that harvested shrimp are compliant to any residue requirements. The frequency of antibiotic use appears limited for larger farms as alternative treatments are sought. Ongoing development to address research gaps, monitor antimicrobial resistance, and increase technical control and barriers for the access and usage of antibiotics is being addressed. This collaborative working group is being led by Ecuador's agricultural stakeholders and the United Nations Food and Agriculture Organization. Results from this working group would likely help to greatly improve data availability, transparency, and understanding of the amount of antibiotics in use, as well as increase the barriers for farmers in obtaining antibiotics. Combined, the effective governance and low use suggests a score of a 4 out of 10 for chemical use. On the other hand, data were not available to robustly estimate the frequency and total volume of antibiotic application, though antibiotic use is known to occur. Small and mid-size farms are more likely to use antibiotics, and the frequency of use may be multiple times per production cycle. Therefore, it is concluded that antibiotics that are highly important for human medicine are used in unknown quantities, which warrants a score of a 2 out of 10. Given this, an intermediate score is justified and the final score for Criterion 4 – Chemical Use is 3 out of 10.

In Ecuador, feed for whiteleg shrimp use fishmeal and fish oil that is made from whole wild fish and from byproduct sources. The fishmeal inclusion level is 20.62% and the fish oil inclusion level is 1.6%; with 47.05% of fishmeal and 31.25% of fish oil sourced from byproducts from the Ecuadorian tuna purse seine fishery, and the remaining 52.95% of fishmeal and 68.75% of fish oil originating from whole fish from the Ecuadorian forage fish purse seine fishery. The Forage Fish Efficiency Ratio (FFER) is low (0.786), meaning that 0.786 mt of wild fish are needed to produce the fishmeal required to produce one mt of farmed shrimp. The sustainability of the source fisheries is moderate and scores a 6 out of 10. Combined with a low FFER, the Factor 5.1 - Wild fish use score is a 7 out of 10. The net protein loss of -63.77% is high and results in score of 3 out of 10 for Factor 5.2 – Net protein gain or loss. The feed footprint is moderate with approximately 20.95 kg of CO_2-eq per kg of harvested protein, resulting in a score of 5 out of 10 for Factor 5.3 – Feed footprint. Altogether, the three factors combine to give a final score of 5.50 out of 10 for Criterion 5 -Feed.

The location, operation, and design of shrimp farms all contribute to the risk of shrimp escaping from farms and affecting wild populations. In Ecuador, farms are sited in areas that are prone to flooding with 8% daily discharge rates into the surroundings watershed, but escape prevention methods like adequate height of perimeter farm dikes, use of screens at inlets and discharge points, and the use of netting during discharge help to reduce the risk of escapes. Therefore, there is a moderate risk of shrimp escaping from farms and Factor 6.1 is scored a 4 out of 10. Whiteleg shrimp are native to the surrounding watersheds but are assumed to be genetically distinct from wild populations and have phenotypic differences due to selective breeding practices. In the case of escaped farmed whiteleg shrimp, it is unlikely that any population level impacts would occur as a result of competitive or genetic interactions with wild whiteleg shrimp, and Factor 6.2 is scored a 4 out of 10. Factors 6.1 and 6.2 combine to give a final numerical score of 4 out of 10 for Criterion 6 – Escapes.

As disease data quality and availability regarding the disease impact on the ecosystem is moderate/low (i.e. Criterion 1 scored 5 out of 10 for the disease category), the Seafood Watch Risk-Based Assessment method was utilized. The historical outbreaks of disease on shrimp farms in Ecuador are well documented, and the industry has demonstrated resilience while adopting practices and techniques to help mitigate against the risk of outbreaks. Mitigation measures include exclusion practices (biosecurity), improved genetic resilience of broodstock programs, farm management practices to improve environmental conditions, and governance structures that help to organize traceability systems, regulations and cooperation within the industry and with other international organizations. These strategies have proven effective at limiting viral disease occurrence on farms despite the openness of the production system. From 2011-2019, there have been zero positive cases for YHV, IMNV, TSV, NHPB, or AHPND/EMS, though WSSV and IHHNV continue to occur, albeit at low prevalence (never exceeding 7%). The biggest disease threat for Ecuadorian farmers is vibriosis. Although *Vibrio spp.* are ubiquitous in aquatic environments, prevalence of clinical disease at any given time is estimated at 20% across the industry. The direct mortality rate vibriosis has upon the industry is unclear, but the mortality rate for the industry overall is 50-90% (personal communication CNA, 2020; HATCH, 2019). It is therefore likely, given low positivity rates of viral diseases, that vibriosis is quite impactful to the industry and commonly results in on-farm mortalities despite the lack of clinical outbreaks. However, *Vibrio* spp. commonly cause mortality amongst wild juvenile shrimp as well, and the low-density production strategy employed by Ecuadorian shrimp farmers suggests that on-farm mortalities do not increase the likelihood of pathogen amplification compared to natural populations. Thus, the impact of disease, mainly vibriosis, is considered to occasionally reduce survival or increases the mortalities on farms and the production system discharges water on multiple occasions during the production cycle without relevant treatment. As such, the risk of disease is considered moderate and results in a final score of 4 out of 10 for Criterion 7 – Disease.

In the 1970s, the Ecuadorian industry relied on wild *L. vannamei* as the source for post larvae, but by 1990 the industry had evolved, investing in the development of roughly 200 hatcheries throughout Ecuador (Stern and Sonnenholzner, 2011). Broodstock facilities began rearing *L. vannamei* helping to shift production reliance from wild *L. vannamei* to a closed production cycle in the 1990s. By the turn of the century, it was illegal to harvest wild *L. vannamei* for aquaculture purposes (Stern and Sonnenholzner, 2011, Acuerdo 106 Prohibicion de captura larva silvestre 2002). After the outbreaks of TSV and WSSV in the 1990s, Ecuador used broodstock selection practices to enhance disease resistance in farm stocks (Moss et al. 2005). All deliberately stocked PLs used in the industry are hatchery-raised and broodstock are selected from farms (Stern and Sonnenholzner, 2011). As such, there is no dependence on wild populations for the source of stock and the numerical score for Criterion 8X – Source of stock is 0 out of -10.

The data regarding the impact that predator control at shrimp farms has on wild species is poor, and the Risk-Based Assessment method was used. Overall, it is understood that Ecuadorian shrimp farms may interact with predators and other wildlife, and farmers primarily utilize nonlethal control methods to limit interactions; thus, it is considered that management practices for non-harmful exclusion are in place. However, there is limited information available to determine whether any mortality (accidental or intentional) is occurring. According to the Organic Code of Environment (2018) it is forbidden to take animals from the wild, unless for hunting purposes for consumption – and there does not appear to be exceptions for shrimp farming. It is unclear whether a permit is needed for take, or whether a permit process is available for shrimp farmers to take animals that are interacting with their farm. There are also protections for endangered species under Ecuadorian law consistent with international treaties of migratory species. Of the known species that interact with aquaculture farms, the majority have a population level of least concern, but 2 species are listed as near threatened, 5 mammal species are listed as threatened and 4 mammal species and 1 bird species are listed as vulnerable. However, there is no documentation that aquaculture operations are using lethal control towards these species or that suggest or claim aquaculture is the reason for the conservation status of these species. It appears that deliberate lethal wildlife control is not permitted, and accidental mortalities are likely to be limited to exceptional cases or are considered highly unlikely to affect the health of the population. Therefore, the score for Criterion 9x – Wildlife Mortalities is -2 out of -10.

Ecuador has broodstock and hatchery production infrastructure that supplies all of the farms demand for *L. vannamei* and Ecuador does not allow the importation of live shrimp. The movement of post larvae from hatchery to grow out farms is not considered to be trans-waterbody. The final numerical score for Criterion 10X – Escape of Unintentionally Introduced Species is 0 out of -10.

Overall, the final numerical score for semi intensively farmed whiteleg shrimp *(Litopenaeus vannamei)* in Ecuador is 4.02 out of 10, which is in the Yellow range. With one Red criteria (Chemicals), the final rank is Yellow and a “Good Alternative” recommendation.

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Introduction

Scope of the analysis and ensuing recommendation

Species
Whiteleg shrimp (*Litopenaeus vannamei)* formerly known as *Penaeus vannamei.*

Geographic Coverage
Ecuador

Production Method(s)
Ponds, semi-intensive

Species Overview
The native wild range for *Litopenaeus vannamei* is along the warm (greater than 20 degrees Celsius) tropical waters of the Eastern Pacific Coast from Sonora, Mexico to Tumbes, Peru. Generally, adults spawn in the open ocean and then the postlarvae (PL) migrate to the coastline settling into mangrove, estuary, and lagoon habitats to complete their juvenile, adolescent and sub-adult life stages (FAO, 2006). Males reach maturation at about 20 grams and females at roughly 28 grams. Females can spawn up to 250,000 eggs (FAO, 2006).

Production system
Shrimp farming is concentrated along the coastal estuaries of the Ecuadorian coastline (see Figure 1). According to Piedrahita (2018a), approximately 80% of Ecuador's shrimp production takes place in Guayas and El Oro provinces, while the remaining production is farmed in Esmeraldas, Manabi, and Santa Elena provinces. Within these provinces, approximately 52% of Ecuadorian shrimp farms (2,057 farms) are located in beaches and bays, accounting for 31% of the total shrimp farming surface area (67,453.16 ha) (Subsecretary of Aquaculture, 2020). There are fewer farms in the highlands (legally defined as private land above the intertidal zone), where roughly 48% of shrimp farms are operating (1,876 farms), but they are responsible for 69% of shrimp farming surface area (149,157.7 ha) (Subsecretary of Aquaculture, 2020). In total, there are 3,933 shrimp farms and of 216,610.91 ha of shrimp farming surface area operating in Ecuador.

Shrimp farming in ponds can be managed at differing intensities, mostly defined by stocking densities, water exchange, the use of mechanical aeration, and the reliance on artificial feed. Most of the production in Ecuador is considered semi-intensive (Hamilton, 2019) with some semi-extensive production occurring (personal communication Piedrahita, 2019). Semi-extensive farming has a lower stocking density than semi-intensive farming conditions and relies primarily on fertilization as a feed source, where semi-intensive production typically utilizes pelleted feed and fertilizer (Seafood Watch, 2020). It is unclear how much semi-extensive production is contributing to the export market but given the current data available, this assessment will evaluate all shrimp production from Ecuador as semi-intensive pond production systems.

Ecuadorian shrimp pond systems are frequent exchange, where water is continuously pumped in and out of the system throughout a cycle. The continuous pumping results in about 8% daily water exchange with zero treatment of water coming into the production system during these exchanges (Twilley, 1989; personal communication Higa, 2020; personal communication Piedrahita, 2020). Water is pumped from natural waterbodies (typically estuaries, but rivers or direct seawater may also be used) into input channels that distribute water into the ponds on one side of the farm, and discharged into output channels on the other side that flow back into the estuary. In areas where tidal fluctuations and flooding risks are prevalent, dikes are constructed up to up to 3-5m in height (Hamilton, 2011; personal communication Hiba, 2020, personal communication Hamilton, 2020). Other areas, where tidal fluctuations, and flooding risks are reduced, like in the interior of the Chone estuary, pond dikes may be constructed about a foot or so above the pond water level (Hamilton, 2011; Hamilton, 2019). Shrimp feed on natural primary productivity enhanced by fertilization and this is supplemented by the application of formulated diets. After ponds are filled with water, the pond environment is fertilized to stimulate primary productivity, and about two weeks later ponds are filled with post larvae with a low stocking density of 8-25 PL/m^2 (personal communication Higa, 2020; personal communication Piedrahita, 2020; Lucien-Brun, 2017).

Ecuador’s pond production model and operation differs from other parts of the world. Since ponds are much larger, shrimp pond management seeks to minimize stress and disease outbreaks through strategies such as low stocking density, specific pathogen resistance breeding, and designing the system to mimic a natural environment with mangroves growing close to the ponds (personal communication Corsin, 2020).

Pond sizes are characterized as small (50 hectares or less), medium (50-250 hectares), and large (250 hectares or more) (personal communication Corsin and van Wageningen, 2020). About 96% of the farms are less than 250 ha, and make up about 65% of the total shrimp farming surface area (Subsecretary of Aquaculture, 2020). These small and medium size enterprises (SMEs) harvest about 3,000 to 4,000 pounds per hectare (personal communication Corsin and van Wageningen, 2020).

Figure 1. Percentage of shrimp ponds in Ecuadorian provinces. (Piedrahita, 2018a).

Production Statistics

Ecuador began farming whiteleg shrimp in the late 1960s/early 1970s (CLIRSEN, 2007; Hamilton 2019; FAO, 2020) and has since developed into a thriving industry with production occurring in five provinces: Guayas, El Oro, Manabi, Esmeraldas and Santa Elena (see Figure 1). There are about 3,933 registered shrimp farms in Ecuador operating on 216,610.91 hectares (Subsecretary of Aquaculture, 2020).The industry also includes 18 feed mills, 20 broodstock facilities, 180 hatcheries, and about 80 processing plants (Piedrahita, 2018a). Four large vertically integrated shrimp companies in Ecuador – Santa Priscila, Expalsa, Omarsa, and SONGA – combine to produce 42% of Ecuador's total shrimp exports (Seafood TIP, 2019).

Import and Export Sources and Statistics

Total shrimp export volume in Ecuador has increased rapidly since the late 1990s and early 2000s after a series of disease outbreaks occurred (first Taura syndrome virus (TSV) in 1992 followed by white spot syndrome virus (WSSV) in 1999), resulting in significant production losses (Lightner, 2011). After export production reached a low in the year 2000, the industry has increased exports by an average of 16% per year (CNA, 2019).

Export volume in 2019 was expected to reach record highs with estimates ranging between 510,000 to 515,000 metric tons (mt) – a 10% increase from 2018 (Evans, 2019). But according to the National Chamber of Aquaculture exports for 2019 were actually 633,000 mt a 25% increase from 2018 (see Figure 2).

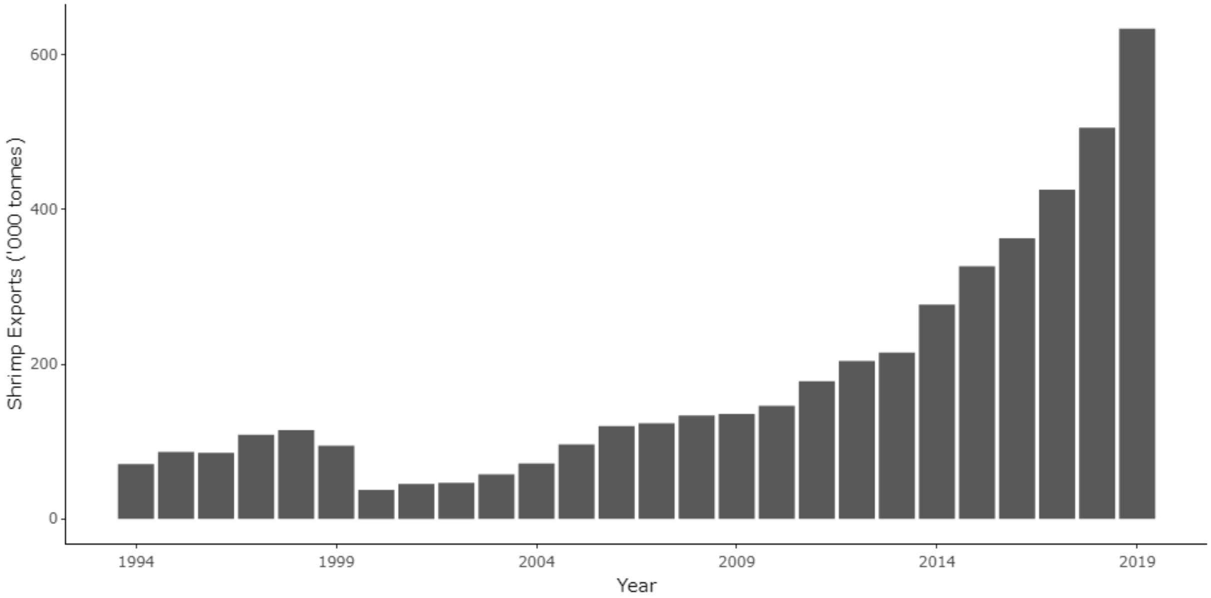

Figure 2. Ecuadorian shrimp export by volume (metric tonnes) from 1994 through June 2019. (CNA, 2019).

The shrimp export market value for Ecuador in 2018 reached a record high of $3.2 billion USD, but was surpassed in 2019 with export values totaling $3.6 billion (CNA, 2019) (see Figure 3). For the most part, as export production has increased, so too has total export value, with some exceptions.

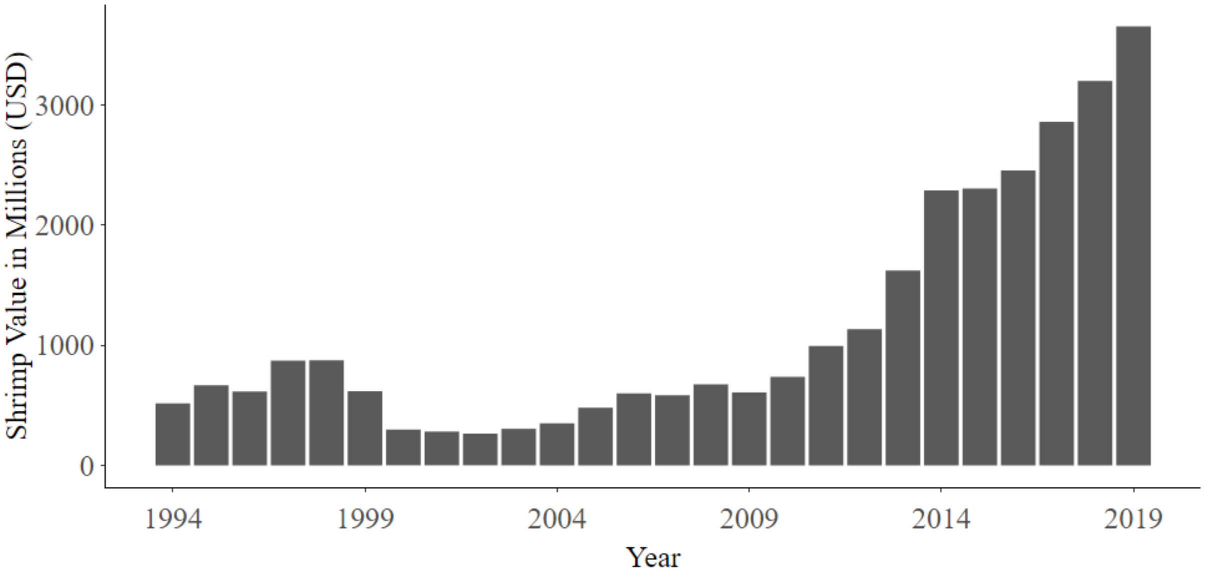

Figure 3. Total Shrimp Export Value (USD) from 1994 to 2018. (CNA, 2019).

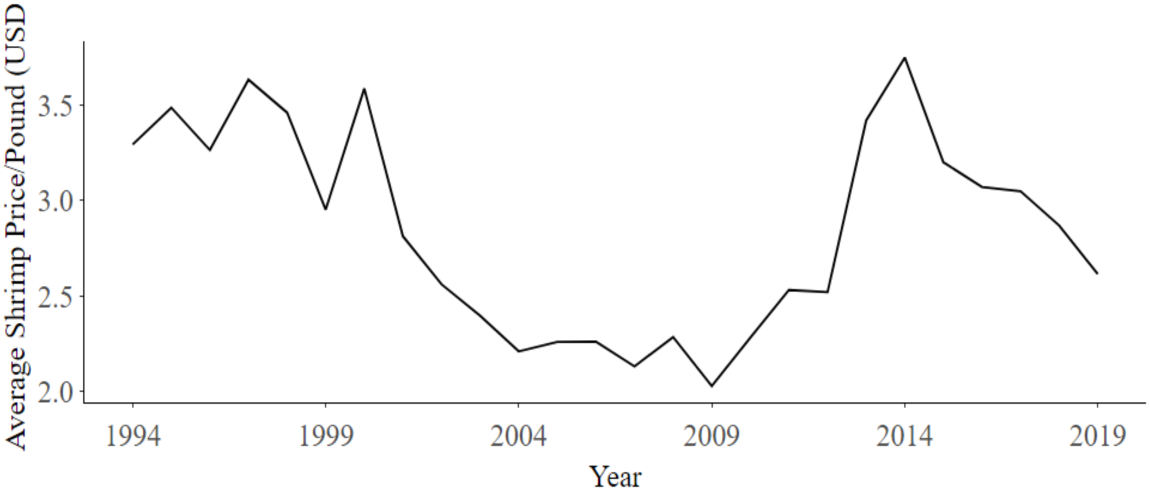

Figure 4. Average Shrimp Price per Pound in U.S. Dollars from 1994 to 2018. (CNA, 2019).

Ecuador's top 10 export markets by volume for shrimp in 2019 include (ranked in order of mt): China, United States, Vietnam, Spain, France, Italy, South Korea, Russia, Colombia, and England. Combined, these countries represent approximately 95% of Ecuadorian shrimp exports (CNA, 2019). About 67% of all exports are headed to Vietnam, China and South Korea. The United States accounts for 12% of the export market and European countries combine to account for ~19%. The market share for Vietnam contracted from 40% in 2018 to 10% in 2019, which may be due to increased security that is now restricting backdoor seafood trade from Vietnam into China (Evans, 2019).

Table 1. Top export markets for Ecuadorian shrimp by market share in 2019. (CNA, 2019).

Country	Percent of export market
China	55%
United States	12%
Vietnam	10%
Spain	6%
France	5%
Italy	4%
South Korea	2%
Russia	2%

In 2018, the United States imported 695,332 mt of shrimp and Ecuador was the third largest supplier to the United States supplying 75,893 mt or 11% of total U.S. shrimp imports in 2018 (See: Table 2) (NMFS, 2019).

Table 2: Top U.S. Import Markets for Shrimp by Market Share in 2018. (NMFS, 2019).

Country	Percent of Import Market
India	36%
Indonesia	19%
Ecuador	11%
Vietnam	8%
Thailand	7%
China	7%

The type of product forms imported from Ecuador are both fresh and frozen. According to the National Marine Fisheries Services, the United States imported 47,910 mt of shell on frozen shrimp, 25,400 mt of frozen peeled shrimp, and 198 mt of fresh shrimp with shell on from Ecuador for all of 2018 (NMFS, 2019). In comparison to other countries, Ecuador ranks 2nd for all fresh shrimp products and 3rd for all frozen shrimp products imported into the United States in 2018[2].

Common and Market Names

Scientific Name	*Litopenaeus vannamei*
Common Name	Pacific white shrimp, Pacific whiteleg shrimp, White shrimp
United States	Shrimp, white shrimp
Spanish	Camarón patiblanco

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[2] Products labeled in the NMFS website that are described as: Canned Shrimp, cold water, other preparations, peeled dried/salted/brine, and prepared dinner were excluded from this analysis.

French	Crevette pattes blanches
Japanese	蛯 (ebi)

Product forms

Ecuador shrimp exports are processed into three products: head on shell on, headless shell on, and peeled. Of all Ecuadorian shrimp exports, 70% are head on shell on, 20% are headless shell on, and 10% are peeled (Seafood TIP, 2019).

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

Data Category	Data Quality	Score (0-10)
Industry or production statistics	7.5	7.5
Management	5	5
Effluent	5	5
Habitat	5	5
Chemical use	2.5	2.5
Feed	5	5
Escapes	2.5	2.5
Disease	5	5
Source of stock	10	10
Predators and wildlife	2.5	2.5
Introduced species	7.5	7.5
Total		**57.5**

C1 Data Final Score (0-10)	**5.23**	**YELLOW**

Brief Summary

The availability and quality of data of the shrimp farming industry in Ecuador is moderate. There are some transparency, organizational, and accessibility issues with data availability. Once data were obtained, the quality of data were considered moderate as gaps in the enforcement of regulations and farms ability to meet prescriptive thresholds were not well detailed. These characteristics are consistent with the Effluent, Habitat, Chemical Use, Feed, Escapes, and Disease Criteria and the Management Data category. Of the information obtained, there was moderate confidence in its ability to provide useful insight of the industry altogether and the final score for Criterion 1 – Data is 5.23 out of 10.

Justification of Rating

Industry and Production Statistics

Total annual statistics for Ecuador shrimp production are available online from the National Chamber of Aquaculture, which also aligns with FAO's FishstatJ software production values. Insights into farm size, production system description, regional profiles, industry organization and infrastructure were obtained from literature sources, the National Chamber of Aquaculture representatives, and the Seafood Trade Intelligence Portal (STIP). U.S. import data was gathered from the United States National Marine Fisheries Service. Data quality and confidence is lowest regarding direct definition of production systems that are operating in Ecuador, as differing definitions exists and supporting documentation of production practices and volume associated with different production types destined for export market is missing. Otherwise, all data are up to date and complete over many years and is considered moderate-high with a score of 7.5 out of 10.

Management and Regulations

Information regarding regulation, management, and enforcement of the shrimp aquaculture industry in Ecuador was obtained from government websites, National Chamber of Aquaculture websites, and correspondence with representatives, literature, and the FAO. Obtaining regulation documentation and understanding the degree of the enforcement was challenging due to the lack of a central location for this information, the frequently evolving nature of this sector and limited transparency demonstrating compliance to these laws by farmers. As a result, data quality regarding management and regulations is moderate and receives a score of 5 out of 10.

Effluent and Habitat

Farm effluent standards and the farm siting process are well detailed and was obtained through correspondence with the National Aquaculture Chamber. The Subsecretary of Aquaculture maintains industry statistics like number of farms, and surface area under culture by zone and province. Conversion of habitat was documented through primary literature. Restoration efforts are detailed by the Undersecretary of Marine and Coastal Management and were obtained through correspondence with the National Chamber of Aquaculture. However, the enforcement of effluent and habitat regulations has limited transparency, and information regarding the science guiding prescriptive thresholds in environmental impacts, as well as the number of farms meeting these limits is not easily obtained. As a result, the data score for Effluent and Habitat Criteria are both 5 out of 10.

Chemical Use

Information regarding the types of chemical treatments used on farms and discharge of ponds was gathered from literature and personal communications, while regulations related to chemical usage and control was detailed in government documents. Frequency of chemical use is not well detailed, and there was no literature citing the impacts, or lack thereof, of chemical treatments on farms to surrounding ecosystems. Enforcement is reliant on the National Control Plan that mandates the registration and approval of all chemical manufacturers for aquaculture purposes and evaluates shrimp products for food safety compliance at processing centers. Therefore, the data quality and confidence of chemical use, frequency of use, and dosage amount of Ecuador shrimp farms is low to moderate and scores a 2.5 out of 10.

Feed
Data for feed use efficiency and feed composition representative of Ecuadorian shrimp farms was gathered from literature, a feed manufacturer in the area, and publicly available Aquaculture Stewardship Council (ASC) audits. Feed ingredients and the sources of fish meal and fish oil was gathered from one feed manufacturer in the area through personal communication. Although this information is insightful, uncertainty exists on whether this information is completely and fully representative of the Ecuador shrimp industry. Therefore, the data quality confidence level is moderate, and the score is 5 out of 10.

Escapes
There was no information regarding the frequency, occurrence, or impact of farmed whiteleg shrimp escapes to wild populations. Wild *L. vannamei* stocks assessments were not available, other than FAO landings data. On-farm escape mitigation practices and insights were gathered from literature sources and industry experts. There is a lack of information studying the potential impacts of escaped *L. vannamei* to the wild stock, and overall, the data quality is considered low to moderate for escapes and is scored 2.5 out of 10.

Disease
Information was gathered from literature, where information regarding impacts and spread of disease within the Ecuador shrimp farming industry was ample, but that of impacts or spread from farms to wild species was limited. Disease incidence rates were obtained from the National Chamber of Aquaculture. Biosecurity and disease prevention measures were detailed in literature and by regulation in the form of good management practices. Overall, the information for the disease criterion is useful, but some uncertainty exists (e.g. transmission from farm to wild species). As a result, the data quality is moderate and scores a 5 out of 10.

Source of Stock
Regulations dictate that all farmed shrimp are produced from domesticated broodstock, and industry statistics demonstrate the size and range of hatchery options to support grow out farms. The data score for Source of Stock is 10 out of 10.

Wildlife and Predator Mortalities
Data was gathered from literature, publicly available ASC audits, and from personal communication with farmers in Ecuador. From these sources a list of animals known to be found on farms was gathered, and one observation of a mortality that appeared to occur on a farm. The population levels and relative conservation concern of these animals was found by referencing the International Union for Conservation of Nature (IUCN). The wildlife control methods and predation prevention measures farmers implement is not well known or detailed. There is some regulation protecting wildlife, and endangered species, but enforcement of these regulations is not clear. As a result, the confidence level of this data and representation of the industry is low to moderate and the score is 2.5 out of 10.

Escape of Secondary Species

Industry organization and structure like number of farms, hatcheries, broodstock facilities, and location of farms by habitat type and regions were found online by the National Chamber of Aquaculture, and the Ministry of Environment. Also, literature defined all estuaries and oceanographic data in Ecuador. These sources combine to give moderate to high confidence level when assessing this criterion, and scores 7.5 out of 10.

Conclusions and Final Score

The availability and quality of data of the shrimp farming industry in Ecuador is moderate. There are some transparency, organizational, and accessibility issues with data availability. Once data were obtained, the quality of data were considered moderate as gaps in the enforcement of regulations and farms ability to meet prescriptive thresholds were not well detailed. These characteristics are consistent with the Effluent, Habitat, Chemical Use, Feed, Escapes, and Disease Criteria and the Management Data category. Of the information obtained, there was moderate confidence in its ability to provide useful insight of the industry altogether and the final score for Criterion 1 – Data is 5.23 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 and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.
- Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.
- Principle: 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

Effluent parameters	**Value**	**Score**
F2.1a Waste (nitrogen) production per ton of fish (kg N ton-1)	51.06	
F2.1b Waste discharged from farm (%)	51%	
F2 .1 Waste discharge score (0-10)		7
F2.2a Content of regulations (0-5)	3	
F2.2b Enforcement of regulations (0-5)	3	
F2.2 Regulatory or management effectiveness score (0-10)		3.6
C2 Effluent Final Score (0-10)		5.00
Critical?	NO	**YELLOW**

Brief Summary

The amount of waste discharged from shrimp farms can be highly variable and dependent on multiple farm practices including feeding rates, water exchange, use of settling ponds or other treatment at exchange or harvest, and sludge disposal. Similarly, the impacts of those waste discharges can be highly variable depending on the characteristics of the receiving waterbody. As effluent data quality and availability is moderate/low (i.e. Criterion 1 score of 5 of 10 or lower for the effluent category), the Seafood Watch Risk-Based Assessment was utilized. Production systems for Ecuador Shrimp are semi-intensive ponds utilizing a feed protein content 31.7%, an eFCR of 1.55, and fertilizer input of 0.93 kg of nitrogen per ton of shrimp produced. This results in a net release 51.06 kg of nitrogen per ton of shrimp. The daily exchange rate for Ecuador shrimp ponds is 8%, and ponds release approximately 51% of the waste produced by shrimp. As a result, 26.04 kg N per ton of shrimp produced is discharged from the farm. Factor 2.1a and Factor 2.1b combine to result in a final Factor 2.1 score of 7 out of 10. The discharge of effluent to the surrounding water bodies is managed by Ecuador's Ministry of Environment. Effluent limits are assigned at the site level with some consideration of the ecological carrying capacity of the receiving water bodies. As a result, the score for Factor 2.2a is considered moderate and a 3 out of 5. The enforcement of effluent limits is moderate.

Agencies and regulations are identifiable, contactable, and measurable, but the transparency, and frequency of monitoring and onsite inspections creates gaps in compliance to effluent standards. Therefore, the score for Factor 2.2b is 3 out of 5. The final score for Factor 2.2 is a combination of Factor 2.2a (3 out of 5) and Factor 2.2b (3 out of 5), and results in a final score of 3.6 out of 10.

Factors 2.1 and 2.2 combined result in a final score of 5 out of 10 for Criterion 2 – Effluent.

Justification of Rating

Risk-Based Assessment:

As effluent data quality and availability is moderate/low (i.e. Criterion 1 score of 5 of 10 or lower for the effluent category), the Seafood Watch Risk-Based Assessment was utilized. This method involves estimating the amount of nitrogenous waste produced per metric ton of shrimp production and the amount of waste discharged from the farm. The content and effectiveness of the regulatory system in managing wastes from multiple farms is used to assess the potential cumulative impacts from the industry as a whole.

Factor 2.1 Waste discharged per ton of shrimp production

Factor 2.1a – Biological waste production per ton of shrimp

The Risk-Based Assessment method estimates the amount of waste nitrogen produced per ton of whiteleg shrimp farmed. To estimate the nitrogenous waste produced by shrimp, nitrogenous inputs and outputs are calculated.

Nitrogenous inputs in Ecuadorian semi-intensive shrimp production include fertilizers applied to stimulate primary productivity, as well as manufactured feeds. Shrimp excrete waste primarily as a result of incomplete digestion and absorption of their feeds, and only a small portion of the nutrients in feed are consumed, assimilated, and retained for tissue growth. Early research by Briggs and Funge-Smith (1994) and Green et al. (1997) indicated that only 24%–37% of the nitrogen (N) and 13%–20% of the phosphorus (P) from feed was retained by shrimp. Similarly, Lorenzen (1999) also reported that 20%–40% of the fed nitrogen was incorporated into shrimp tissue. These ranges are still considered valid today, though considerable investment has gone into increasing the efficiency of shrimp feeds and have resulted in higher phosphorus retention in shrimp (Dien et al., 2018; Van Nguyen and Maeda, 2015).

The average protein content of shrimp feed in Ecuador is 31.70%, which is the weighted average representing 23 different data points (20 from ASC reports, 2 from peer reviewed literature, and 1 from different diet formulas from Skretting). The following methodology was used to calculate the weighted average: according to Seafood Watch, 10% of all Ecuador whiteleg shrimp production is currently certified by ASC, therefore a weighted average of 10% was applied to all ASC values, and 90% weighted average was applied to all other sources. The use of a single eFCR value to represent an entire industry is challenging. The difficulty is rooted in the differences in shrimp genetics, feed formulations, farm practices, occurrence of disease, and more. After reviewing available data, an industry average eFCR of 1.55 is considered representative of Ecuadorian whiteleg shrimp production (personal communication Massaut; personal communication Higa, 2020; ASC, 2019; Lucien-Brun, 2017; SFW, 2014; Hasan and Soto, 2017; Molina and Espinoza, 2018; Vega and Beillard, 2015; Starostina, L., 2016; Skretting, 2016).

Ecuadorian shrimp farms typically apply fertilizer to stimulate primary production (Sonnenholzner, 2002; Hamilton, 2019; SFW, 2014; Twilley, 1999; Sonnenholzner and Boyd, 2000). Current estimates regarding fertilizer application rates were unavailable in primary literature, but was estimated by an industry expert. Fertilizers commonly used include wheat meddling, rice bran, urea, sodium nitrate, calcium nitrate, nutrilake, bovine manure, and molasses (personal communication Higa, 2020). The quantity of applied fertilizer varies based on the fertilizer and production strategy of the farmer, but application estimates are provided: urea (0.29 kg per ha), sodium nitrate (1.46 kg per ha), calcium nitrate (0.29 kg per ha), Nutrilake (11.7 kg per ha), and bovine manure (0.59 kg per ha), with reported average total volumes of fertilizer of 14.34 kg per hectare (personal communication Higa, 2020).

Seafood Watch expresses nitrogenous input from fertilizers as kg N per metric ton (mt) of shrimp production. Assuming an average productivity of Ecuador *L. vannamei* farms of 2.93 mt/ha[3], average application of 14.34 kg/ha of fertilizer, and an average nitrogen content of 19% for all the fertilizers applied[4], it is calculated that the average nitrogenous input from applied fertilizers is 0.93 kg N per mt of shrimp production. In the absence of additional information, this estimate is used in calculations below.

The calculations that were carried out using these figures to determine waste nitrogen per ton of shrimp produced are as follows:

N input per ton of shrimp produced:

[(feed protein) x N content factor (0.16) x eFCR x 10] + (fertilizer per mt) = 79.55 kg N t^{-1}

N content of harvested shrimp:

(protein content of whole shrimp) x N content factor (0.16) x 10 = 28.48 N t^{-1}

Waste N produced per ton fish produced (2.1a):

N input – harvested N = 51.06 kg N t^{-1}

Therefore, the net excretion of nitrogen in soluble and particulate wastes is 51.06 kg N per ton of whiteleg shrimp production.

Factor 2.1b – Production system discharge

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[3] the average productivity of Ecuador shrimp is calculated as the total (metric tonnes of production in 2019) / (total surface area in 2020), which is (633890.46 mt) / (216610.89 ha) = 2.93 mt/ha (CNA, 2020; Ministry of Environment, 2020)

[4] Average nitrogen content for Urea is 46% (University of Minnesota Extensions, 2020), sodium nitrate is 16% (IPNI, 2020), calcium nitrate is 16% (Vitosh, M.L., 1996), nutrilake is 14.5% (SQM, 2020), and bovine manure is 3% (University of Nebraska-Lincoln, 2020). The calculated average is therefore 19%.

Ecuadorian shrimp pond systems feature frequent water exchange at an average daily rate of 8% (Twilley, 1989; personal communication Hiba, 2020). The daily exchange rate of 8% is a representative average of the industry as most farms are typically 5-8%, but some farms exchange between 10-12% (personal communication CNA, 2020; personal communication, Higa). The most recent primary literature publication, Twilley (1989) reported 10% as an average daily exchange, but production practices have likely changed since its publication. Ponds receive water from constructed inlet channels, where water is pumped from a neighboring waterbody (such as an estuary, seashore, or river) into the channel and then distributed to ponds. Daily discharge exits directly into drainage channels, which then return water directly into the waterbody (personal communication Hiba, 2020; personal communication Corsin, 2020; personal communication Piedrahita, 2020). Figure 5 shows a "typical Ecuadorian shrimp pond discharge system" (Hamilton, 2011), with a concrete and wooden dam that controls water height and discharge. During harvest, ponds are drained completely, directly into the drainage channels (Lucien-Brun, 2017; personal communication Higa, 2020). There is no treatment of inflow or outflow water in Ecuadorian systems, and sedimentation ponds are not typically used (personal communication Hiba, 2020; personal communication Corsin, 2020; personal communication Piedrahita, 2020).

According to the Seafood Watch Aquaculture Standard, ponds with an average daily exchange >3% are given a basic production system discharge score of 0.51, indicating that 51% of waste produced by shrimp are considered to be discharged to the environment. Thus, the estimated total waste discharged per ton of shrimp produced is 26.04 kg N t^{-1}. This equates to a final score for Factor 2.1 – Waste discharged per ton of shrimp of 7 out of 10.

Figure 5. "A Typical Ecuadorian Shrimp Pond Discharge System. Picture was taken near the village of Salinas on the Northern side of Chone Estuary, January 2008." (Hamilton, 2011).

Factor 2.2 Management of farm-level and cumulative impacts

Factor 2.2a: Content of effluent management measures

Shrimp farming in Ecuador is subject to effluent regulations at the federal level and is overseen by the Ministry of Environment, and the Vice Ministry of Aquaculture and Fisheries Undersecretary of Aquaculture (Unified Secondary Legislation of the Ministry of the Environment; Organic Environment Code, 2018). The legislative tools that describe the process and ecological limits that these agencies use to govern shrimp aquaculture effluent are the Organic Environment Code (2018) and the Unified Secondary Legislation of the Ministry of the Environment: Environmental Quality and Discharge of Effluents to Water Resources.

All farms must comply with effluent discharge limits, which are determined by the location of effluent discharge and the receiving water body type. The Environmental Quality and Discharge of Effluents to Water Resources outlines the prescriptive limits depending on the discharge location of the shrimp aquaculture farm. All farms must document where the discharge is occurring, the rate of the discharge, the frequency of discharges, and what sort of effluent treatments are implemented (Environmental Quality and Discharge of Effluents to Water Resources, Article 5.2.2.1c). Prescriptive effluent limits for shrimp aquaculture farms discharging into marine or brackish waterbodies in the surf zone or deeper waters are described in Table 3. These limits are determined based on the carrying capacity of receiving water bodies and developed by the Ministry of Environment (Unified Secondary Legislation of the Ministry of the Environment: Environmental Quality and Discharge of Effluents to Water Resources, Article 5.2.5.2; personal communication Piedrahita, 2020). However, the methodology by which carrying capacity was determined could not be found, and it appears that these prescriptive limits are the same for all aquaculture ponds discharging into marine waterbodies throughout Ecuador.

Evidence of compliance to effluent limits must be submitted annually. To comply, water quality samples are taken from the farm at least twice a year - once in the rainy season and once in the dry season - by an accredited third party (personal communication CNA, 2020). For each seasonal measurement, water samples are taken from two locations; one sample is taken at the pumping station, and the second sample is taken about 50-100m from the outlet channel (personal communication, CNA, 2020). Every sample is attributed with GPS coordinates. The sampling and laboratory analysis must be completed by an accredited lab (ISO 17025), which helps to ensure chain of custody (personal communication CNA, 2020). The results are then submitted annually to the competent authority (personal communication CNA, 2020). The results of these samples are not made public but can be provided by the competent authority upon request (personal communication CNA, 2020). Onsite randomized inspections do occur; a farm will be randomly inspected sometime within the first year of operation, and once every three years after that.

Table 3. Limits of Discharge to a Marine Water Body. (Unified Secondary Legislation of the Ministry of the Environment: Environmental Quality and Discharge of Effluents to Water Resources).

Parameter	Unit	Maximum daily discharge limits – surf zone	Maximum daily discharge limits – deeper water
Biochemical Oxygen Demand (5 days)	mg/l	200	400
Chemical Oxygen Demand	mg/l	400	600
Floating Matter	Visibility	Absent	Absent
Total Nitrogen	mg/l	40	40
pH		6-9	6-9
Total Suspended Solids	mg/l	250	250
Sulphides	mg/l	0.5	0.5

Organochlorine Compounds	µg/l	50	50
Organophosphates Compounds	µg/l	100	100
Temperature	Celsius	<35	<35

Overall, management of farm effluent is controlled through prescriptive discharge limits, yearly water quality sample submissions and random onsite inspections. The effluent limits are the same throughout the production cycle and, as defined in the legislative text, are set at the site level with documented third party analysis occurring twice a year with water samples taken at the inflow and at the discharge of the farm outlet channel. Attempts to find more information about how these farm level effluent limits have considered the cumulative level impact of farms throughout a watershed or area were unsuccessful. Furthermore, how the carrying capacity of each estuary has been assessed or determined is unclear, since the effluent limits are the same for every estuary. Therefore, the management of effluent is considered moderate, with a management system that is based on relevant ecological factors at the site level but not at the cumulative or area level.

As a result, the effluent management system in Ecuador is considered moderate and the final score for Factor 2.2a – Content of effluent management measures is 3 out of 5.

Factor 2.2b: Enforcement of effluent management measures

The Ministry of Environment enforces the environmental and effluent standards described in the Organic Environment Code (2018) and the Unified Secondary Legislation of the Ministry of the Environment: Environmental Quality and Discharge of Effluents to Water Resources. These two legislative pieces combine to prescribe limits to shrimp aquaculture discharge into the environment, methodology of water sampling, and required documentation for farms. This is enforced through annual reporting, and through random onsite inspections.

Annual reports submitted by industry summarize the results of water quality samples that are taken at least twice a year - once in the rainy season and once in the dry season - by an accredited third party (personal communication CNA, 2020). The sampling and laboratory analysis must be completed by an accredited lab (ISO 17025), which helps to ensure chain of custody (personal communication CNA, 2020).

Onsite inspections by the Ministry of Environment occur randomly but depends on when operations started. If a farm has been operating for less than 1 year, then it will be randomly inspected sometime within the first year of operation. If a farm has been operating for more than one year, than randomized site inspections occur once per three years (Organic Environment Code, 2018; personal communication Piedrahita, 2020). Farmers are notified before Ministry of Environment officials come to the farm, to ensure farm managers are present and able to help collect water quality samples. The sampling process is described in 2.2a.

If non-compliance is observed in either the onsite inspection or annual report, the farm must create and submit an approved action plan within 15 days of notification of non-compliance that details steps to be taken to correct and verify compliance (COA Regulation Articles 505, 506, 507). Depending on the frequency and severity of non-compliance, the resulting punishment is increased and can result in the loss of permits to the farm, and/or severe fines (Organic Environment Code, 2018). Falsifying any of this information may be punished with imprisonment up to three years (Environmental Quality and Discharge of Effluents to Water Resources, Article 255). Additionally, farms must pay for any costs that result from environmental damages that are observed due to effluent discharges by the farm, enforced by the Ministry of Environment (Environmental Quality and Discharge of Effluents to Water Resources, Article 5.2.2.1c).

The cumulative impact of effluent discharge from aquaculture farms in Ecuador estuaries is not well understood. Hamilton (2019) suggests that shrimp aquaculture may be contributing to harmful algal blooms (HABs) observed in Ecuador, but this field of research is in its early stages. From 1968 to 2017, 132 HAB events have occurred along the coastline of Ecuador with 67 HAB events occurring from 1997 to 2017 with various plankton population dynamics and toxicity (Borbor-Cordova et al., 2019). According to the study by Borbor-Cordova et al. (2019), the main drivers identified for HABs in coastal Ecuador are oceanographic characteristics – mainly upwelling and El Niño events – but did list terrestrial nutrient inputs (inclusive of aquaculture production) as a contributing factor.

Overall, enforcement of effluent discharge regulation appears to be moderate. Enforcement organizations are identifiable and contactable, with activity at the area-based scale. Monitoring data for compliance to effluent discharge limits are submitted by industry annually, and while these reports are not published, they can be made publicly available upon request. Onsite inspections occur within the first year of operations beginning, but then occur once per three years. Compliance with effluent standards is mandatory; failure to comply may lead, depending on the severity and frequency of non-compliance, to establishing an action plan, revoking permits, fines and/or even imprisonment. However, the limited frequency of inspections, and the lack of documentation demonstrating the consideration and enforcement of cumulative impacts, limits the effectiveness of enforcement measures. Therefore, the score for Factor 2.2b is a 3 out of 5.

The final score for Factor 2.2 is a combination of Factor 2.2a (3 out of 5) and Factor 2.2b (3 out of 5), and results in a final score of 3.6 out of 10.

Conclusions and Final Score

The amount of waste discharged from shrimp farms can be highly variable and is dependent on farm practices including feeding rates, water exchange, use of settling ponds or other treatment at exchange or harvest, and sludge disposal. Similarly, the impacts of those waste discharges can be highly variable depending on the characteristics of the receiving waterbody. As effluent data quality and availability is moderate/low (i.e. Criterion 1 score of 5 of 10 or lower for the effluent category), the Seafood Watch Risk-Based Assessment was utilized.

Semi-intensive production of shrimp in Ecuador utilizes feed with a protein content 31.7%, an eFCR of 1.55, and fertilizer input of 0.93 kg of nitrogen per ton of shrimp produced. This results in a net release 51.06 kg of nitrogen per ton of shrimp. The typical daily water exchange rate used in Ecuadorian shrimp ponds is 8%, and ponds release approximately 51% of the waste produced by shrimp. As a result, an estimated 26.04 kg N per ton of shrimp produced is discharged from farms. Factor 2.1a and Factor 2.1b combine to result in a final Factor 2.1 score of 7 out of 10. The discharge of effluent to the surrounding water bodies is managed by Ecuador's Ministry of Environment. Effluent limits are assigned at the site level with some consideration of the ecological carrying capacity of the receiving water bodies. As a result, the score for Factor 2.2a is considered moderate and a 3 out of 5. The enforcement of effluent limits is moderate. Agencies and regulations are identifiable, contactable and measurable, but the frequency of monitoring and onsite inspections creates gaps in the enforcement of compliance to effluent standards. Therefore, the score for Factor 2.2b is 3 out of 5. The final score for Factor 2.2 is a combination of Factor 2.2a (3 out of 5) and Factor 2.2b (3 out of 5), and results in a final score of 3.6 out of 10.

Factors 2.1 and 2.2 combined result in a final score of 5 out of 10 for Criterion 2 – Effluent.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Habitat parameters	**Value**	**Score**
F3.1 Habitat conversion and function		4
F3.2a Content of habitat regulations	2	
F3.2b Enforcement of habitat regulations	3	
F3.2 Regulatory or management effectiveness score		2.40
C3 Habitat Final Score (0-10)		**3.47**
Critical?	NO	**YELLOW**

Brief Summary

Significant conversion of estuary habitat to shrimp farms occurred prior to 1999 in Ecuador as mangroves and estuaries were the preferred location for shrimp farm development. Since 1999, new development of dry shrub habitat, highlands, along the estuary edge is ongoing. In total, the shrimp farming industry has increased by 41,357.39 ha since 1999 with all expansion occurring outside of the estuary along the estuary edge. Over the past 3 years, 6,334.98 ha of habitat along the estuary edge has been converted to shrimp farming area. Considering that the estuary and the estuary edge (dry shrub habitat) are fundamentally connected habitats, the significant expansion of shrimp farms into the estuary edge since 1999 has extended the impacts of the shrimp farming industry from within the estuary to the estuary edge. Therefore, considering the historic loss of functionality in the broader estuarine ecosystem, recent marginal conversion on the estuary edge is not considered to represent ongoing loss of functionality in the estuary and the final score is 4 out of 10. The management system does require most farms to be sited according to ecological principles and/or environmental considerations, but there are limited considerations of cumulative habitat impacts and loss of ecosystem services. As a result, the final score for Factor 3.2a is 2 out of 5. These management measures are enforced by organizations that are identifiable and contactable. The size and scale of these agencies and co-management groups are not well understood, so it is challenging to determine whether they are able to effectively manage the environmental regulations and habitat measures outlined. About 31% of shrimp farms are considered low impact and are operating in the highlands, where all new development has occurred since 1999. Low impact farms are not as rigorously vetted prior to aquaculture production as medium and high impact farms, which are required to be sited with EMP and EIA. As a result, there are limitations that reduce the effectiveness of habitat enforcement. Therefore, the score for Factor 3.2b is 3 out of 5.

The score for Criterion 3 – Habitat is a combination of the scores for Factor 3.1 – Habitat conversion and function (4 out of 10) and Factor 3.2 – Farm siting regulation and management (2.40 out of 10), and the final score is 3.47 out of 10.

Justification of Rating

Factor 3.1. Habitat conversion and function

Ecuadorian shrimp farms are concentrated in seven estuaries along Ecuador's coastline – the Muisne Estuary, Cojimies Estuary, Chone Estuary, Isla Puna North, Isla Puna, Guayas Estuary, and the estuaries of El Oro Province (Grande Estuary and many rivers to the north) (Hamilton, 2019). These estuary systems consist of coastal watershed habitats that have high ecological value and are characterized as seasonal wetlands, salt flats or salt marshes, and mangrove forests (Piedrahita, 2018a; Hamilton, 2019; and Twilley et al. 2001; Anderson, 2014). Ecuador's coastline is ecologically significant with a total of 19 Ramsar designated areas and is also where the Gulf of Guayaquil can be found, which is "the largest estuarine ecosystem on the Pacific coast of South America." (Ramsar, 2019; Twilley et al., 2001).

The development of commercial shrimp farms and the subsequent conversion of estuary habitat began in the late 1960s/early 1970s (CLIRSEN, 2007; Hamilton 2019; FAO, 2020). Evidence of estuary habitat conversion is documented through two primary sources CLIRSEN (2007) and Hamilton (2019). Both of these studies document land use change of Ecuador's estuary habitats by utilizing satellite imagery over time. Although the precision of the resulting data may be debated, it is the best historical data available. Combined, these two reports estimate land use change of Ecuador's estuaries from 1969 to 2014. More recent data documenting farm statistics by Province was made available by the Ministry of Environment (data for 2020), and the National Chamber of Aquaculture (data for 2017) (Piedrahita, 2018a).

To evaluate the type and severity of habitat conversion through time, a review of Hamilton (2019) is presented by Province starting from North to South. Habitat conversion by estuary is aggregated to the country level, followed by the most up to date summary of where farms are currently operating. This insight is then summarized to provide a comprehensive review and summary of shrimp farm habitat conversion through time in Ecuador.

Esmeraldas

Esmeraldas is the Northern most coastal Province in Ecuador and has two estuaries where shrimp farming has developed: the Cayapas-Mataje Estuary and the Muisne Estuary. Shrimp farming has not significantly driven land use change in the Cayapas-Mataje Estuary, as it only occupies roughly 2% of the estuary region as of 2014 (Hamilton, 2019). The Muisne Estuary is approximately one tenth the size of the Cayapas Mataje Estuary and is where the majority of shrimp farms are located in the Esmeraldas Province (Hamilton, 2019). In 1970, before shrimp farming in the Muisne estuary began, 52% of the estuary was occupied by mangrove forests (Hamilton, 2019). But as of 2014, mangrove forests occupy about 24% of the region and shrimp farms account for about 36% of the estuary region, making shrimp farms now the dominant land use in the Muisne estuary (Hamilton, 2019).

At the time of writing, total shrimp farming area in Esmeraldas is about 1,472.3 ha and there are about 540 farms (Ministry of Environment, 2020).

Manabi

The Manabi Province has two significant estuaries where shrimp farms operate: the Chone Estuary and the Cojimies Estuary. The majority of these estuaries were once covered by mangrove forests, but now shrimp farming is the dominant land use type. In 1970, the Cojimies Estuary was covered by approximately 51% mangrove forests and there were no shrimp farms, but by 2014 mangrove forests accounted for 15% of the land use while the major land use became shrimp farms occupying 49% of the estuary (Hamilton, 2019). Similarly, in 1970 the Chone Estuary consisted of approximately 49% of mangrove forests, and zero shrimp farms. By 2014, roughly 45% of the land use in the estuary was shrimp farms, and 25% of the estuary land use was mangrove forests (Hamilton, 2019).

At the time of writing, 865 farms are operating in the Manabi province for a total of 20,118.07 ha (Ministry of Environment, 2020).

Santa Elana

The Santa Elana Province has the fewest shrimp farms and lowest shrimp farming area of any of the coastal Ecuador Provinces, with 73 shrimp farms and 7,126.59 ha operating as of the year 2020 (Ministry of Environment, 2020). Information documenting land use change through time was not readily available.

Guayas

According to Hamilton (2019), data for pre-shrimp farming land use is unavailable for the Guayas Province. By 1985, 11% of the Guayas estuary's land use was shrimp farms, and 46% was mangrove forests (Hamilton, 2019). In 2014, 22% of the estuary was occupied by shrimp farms and 39% remains mangrove forests. It is estimated that the "amount of mangrove forest lost directly to shrimp farms totals 21,565 ha and is the largest single LULC [land use and land cover change] transition in the estuary." (Hamilton, 2019).

At the time of writing, there are 1,360 shrimp farms operating on 132,710.26 ha (Ministry of the Environment, 2020).

El Oro

The El Oro Province has numerous rivers including the Grand Estuary. From 1977 to 2014, shrimp farming surface area increased to become the dominant land use type of the El Oro estuary region. In 1977, 47% of the El Oro estuary region was covered by mangroves and it was the dominant single land use type, while shrimp farming covered 5% of the estuary area. However, by 2014, mangrove coverage decreased to 26% of the land surface area, and shrimp farming covered 55% of the estuary land surface area (Hamilton, 2019).

At the time of writing, 41,913.1 ha and 1,095 farms are operating in the El Oro Province (Ministry of Environment, 2020).

Country Level Estuary Impacts

Shrimp farming is now the dominant single land use for every estuary along coastal Ecuador, except for the Cayapas-Mataje Estuary (Hamilton, 2019). In tota,l from 1984 to 2020, shrimp farming surface area expanded from roughly 89,368.3 ha to 216,610.9 ha (see Figure 6), with 55,920 ha of mangrove forests converted to shrimp farms (Hamilton, 2019). In 2014, the aggregate estuary land use cover at the country level estimates that 36% of the estuary space is mangrove forests, while 36% is water, and 28% of all estuary space consists of shrimp farms (Hamilton, 2019). If excluding Cayapas-Mataje Estuary (a conservation area with little shrimp farming), then the national land use of Ecuador's estuaries are "34% mangrove forest, 35% water, and 31% shrimp farms…an almost equal split across the three LULC classes." (Hamilton, 2019). Although shrimp farming is not the only driver for the conversion of mangrove forests in Ecuador, it is the "single greatest LULC [land use and land cover] change along coastal Ecuador" from 1970 to 2014 (Hamilton, 2019).

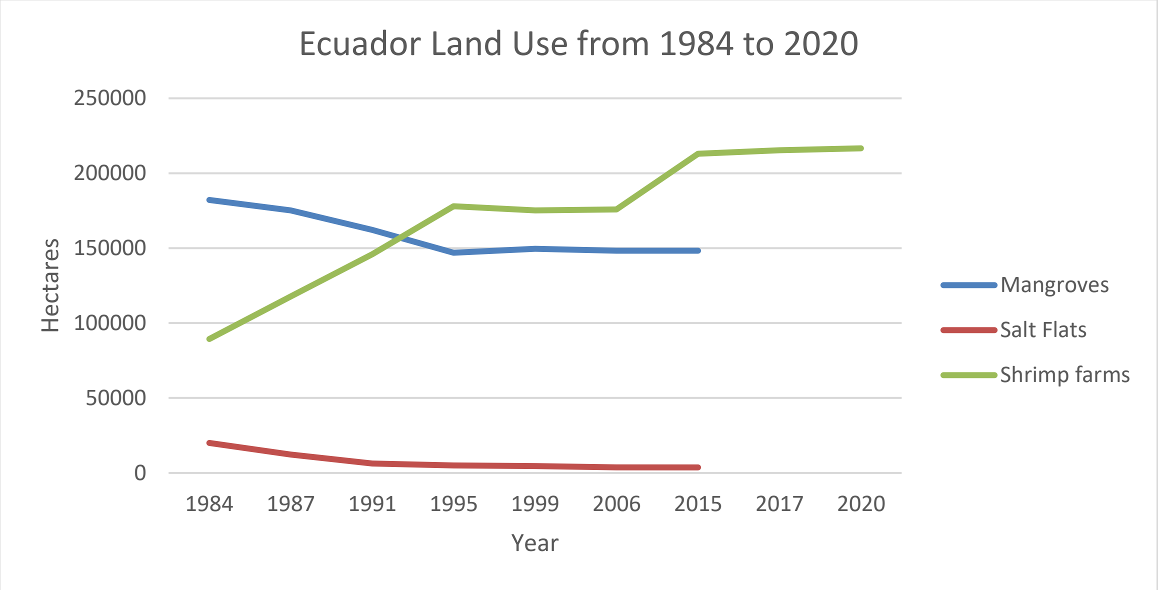

Figure 6: Land use in Ecuador from 1984 to 2020. The total surface area of mangroves and salt flats have decreased through time, while shrimp farm surface area has continued to expand. Source (Ministry of Environment, 2020; CLIRSEN, 2007; Piedrahita, 2018a).

Since 1999, estuary habitat is no longer being converted to shrimp farms (Piedrahita, 2018a; CLIRSEN, 2006; Ministry of Environment, 2020, Hamilton, 2019) due to a change in environmental protections and enforcement (see Factor 3.2). As a result, new shrimp farms could no longer develop in the estuaries and the expansion of existing shrimp farms within the estuaries were no longer allowed. However, the total shrimp farming surface area continues to expand.

To document the most recent growth (after 1999), the CLIRSEN (2007) study estimates shrimp farming surface area from 1999 to 2006. This dataset is combined with shrimp farming data from 2017 and 2020 (Ministry of Environment, 2020; Piedrahita, 2018a) to document and estimate the growth of shrimp farming over the past 20 years. From 1999 to 2020, shrimp farming surface area increased by 41,357.39 ha which accounts for about 20% of the total shrimp farming area to date. The geographical location of this development is not known, but since development could not legally occur within the estuary, it is assumed this expansion occurred along the estuary edge and is partly consistent with Hamilton's (2019) observation noting that in 2014 the development of the estuary edge had already begun.

More recent data from 2017 and 2020 helps to explain in what provinces ongoing shrimp farming expansion is occurring. Farms are now technically sited in either "Beaches and Bays" or "Highlands". Beach and bay areas are defined as the intertidal zone and it is a public resource belonging to the State, and no farms have been sited there since 1995 (personal Communication Piedrahita, 2020). Highland is the term used to describe land that is private (Law of Aquaculture and Fisheries, 2020) and consists of dry shrub habitat that is at the edge of the intertidal zone (personal communication CNA, 2020). Recent trends of shrimp farming development in Ecuador is assessed by the changes observed in beaches and bays and highland farming area from 2017 to 2020 (see Table 4). From 2017 to 2020, there has been a decrease of 93 farms, and a decrease of 5,144.84 ha of shrimp farm surface area in the beaches and bays. In the highlands, there has been an increase of 151 farms, and an increase of 6,334.98 ha of shrimp farming surface area from 2017 to 2020. About 95% of the highland expansion has occurred in the Provinces of Guayas (41%), El Oro (34%), and Manabi (20%).

As of 2020, there are 3,933 farms operating in Ecuador. Approximately 52% of farms (2,057) are located in beaches and bays accounting for 31% of the total shrimp farming surface area (67,453 ha) (Subsecretary of Aquaculture, 2020). There are fewer farms in the highlands, where roughly 48% of farms are operating (1,876), but they are responsible for 69% of the shrimp farming surface area (149,157.7 ha) in Ecuador (Subsecretary of Aquaculture, 2020). See Table 4 for a summary of shrimp farm siting statistics.

Table 4: Shrimp farming production statistics documenting the number of farms and surface area by province, year, and zone. Source: Subsecretary of Aquaculture, 2020; Piedrahita, 2018b.

		Guayas			El Oro			Manabí		
		2017	2020	Change	2017	2020	Change	2017	2020	Change
Highlands	Surface Area	94,616.28	97,232.72	2,616.44	20,751.23	22,916.14	2,164.91	10,970.19	12,245.32	1,275.13
	Farms	595	649	54	344	456	112	448	448	0
Beach and Bay	Surface Area	37,506.26	35,477.54	-2,028.72	20,885.89	18,997.53	-1,888.36	8,991.99	7,872.75	-1,119.24
	Farms	768	711	-57	652	639	-13	428	417	-11
Total	Surface Area	132,122.63	132,710.26	587.63	41,637.12	41,913.67	276.55	19,962.17	20,118.07	155.90
	Farms	1,363	1,360	-3	996	1095	99	876	865	-11

		Esmeraldas			Santa Elena			All Provinces		
		2017	2020	Change	2017	2020	Change	2017	2020	Change
Highlands	Surface Area	10,033.78	10,286.33	252.55	6,451.29	6,477.23	25.94	142,822.77	149,157.74	6,334.97
	Farms	267	261	-6	71	62	-9	1725	1876	151
Beach and Bay	Surface Area	4,575.83	4,455.98	-119.85	638.17	649.36	11.19	72,598.14	67,453.16	-5,144.98
	Farms	292	279	-13	10	11	1	2150	2057	-93
Total	Surface Area	14,609.61	14,742.31	132.70	7,089.26	7,126.59	37.33	215,420.79	216,610.90	1,190.11
	Farms	559	540	-19	81	73	-8	3875	3933	58

Overall, significant conversion of estuary habitat to shrimp farms occurred prior to 1999 in Ecuador. According to the analysis of Hamilton (2019), shrimp farms are the dominant single land use type in all of Ecuador's estuaries (except for the Cayapas-Mataje Estuary) which has resulted in the loss of estuary habitat functionality. Since 1999, new development of dry shrub habitat along the estuary edge, known as highlands, is ongoing. The estuary edge habitat is fundamentally connected to the estuary and is considered to be part of the broader high-value estuarine ecosystem. The ongoing conversion along the estuary edge is considered marginal. There is an estimated conversion of 41,357.39 ha of estuary edge habitat to shrimp farms from 1999 to 2020, but the most recent data provided from 2017-2020 states that a total of 6,334.98 ha of dry shrub habitat was converted to shrimp farms. This conversion and expansion are considered marginal and is converting an already altered estuary ecosystem which had lost its functionality prior to 1999. Therefore, considering the historic loss of functionality in the estuarine ecosystem occurred prior to 1999, the documented recent marginal conversion of the estuary edge is not considered to represent ongoing loss of functionality and the final score is 4 out of 10.

Factor 3.2. Farm siting regulation and management

Factor 3.2a: Content of habitat management measures

In this factor, regulations relating to the protection of habitat from impacts due to shrimp farm siting are assessed, which includes the permitting process and known mangrove rehabilitation efforts.

The organizations responsible for managing aquaculture activities and enforcing environmental protections include the Vice Ministry of Aquaculture and Fisheries, the Ministry of Environment, and custodias. The Vice Ministry of Aquaculture and Fisheries and the Ministry of Environment are responsible for overseeing the leasing of new aquaculture sites and regulating farm operations (Vega and Beillard, 2015). Custodias are formalized ancestral groups that are certified guardians of the mangroves (Bietl, 2016).

The Ministry of Environment is additionally responsible for regulating the farm siting process outlined by the Organic Environment Code (2018). The characteristics of a proposed project, such as a shrimp farm development, and the magnitude of their environmental impacts or risks are assessed by the Unique Environmental Information System, which determines the type of environmental permit to be granted. This process classifies a project as having an insignificant, low, medium, or high risk to impact the environment (Code for the Environment, 2018) and the proposed size of the farm is a contributing characteristic (personal communication, CNA, 2020). Generally, if the farm is greater than 100 hectares then the project is considered medium to high impact and must apply for an environmental license (personal communication, CNA, 2020; Code for the Environment, 2018). Farms less than 100 hectares are typically classified as low impact and only have to seek an environmental registry (personal communication, CNA, 2020; Code for the Environment, 2018). The size threshold of 100 hectares and the corresponding risk level of a project is expected to be changed to 25 hectares with the passing of the updated

Fisheries and Aquaculture Law of 2020 and the following legislations (personal communication CNA, 2020).

If a farm is considered low impact, then it must take the necessary steps for environmental registry. This includes simply registering as an operating farm with the Ministry of Environment and the Vice Ministry of Aquaculture and Fisheries and complying to all aquaculture regulations (Code of the Environment, Article 429, 2018).

If a farm is considered to have medium to high impact, then it must undergo the process for environmental license. This includes providing documentation of the proposed aquaculture farm including the geographic layout, the projects location, an economic study, an environmental impact assessment (EIA), and an environmental management plan (EMP) to the Ministry of Environment and the Vice Ministry of Aquaculture and Fisheries. The purpose of the environmental impact assessment is to evaluate the potential environmental damages and impacts that may occur from the proposed projects construction and operation, and to ensure that farms are not sited in protected areas. The environmental impact assessment then informs the environmental management plan (EMP), which describes the mandatory measures that are taken by the applicant to minimize or prevent environmental impacts. Specifically, the EMP must address disposal of farm operation waste (e.g. food waste, cardboard paper, and hazardous waste), storage (chemicals, and hazardous waste), pest control, and septic facilities. After environmental impacts are described, assessed, and a plan proposed, the documentation is presented to the community by a sociologist accredited by the Ministry of Environment for approval by different land use stakeholder groups who operate in the area. Final approval results in a Ministerial Agreement and operational permits from the Vice Ministry of Aquaculture and Fisheries.

To estimate the amount of shrimp farming projects that are classified as low or medium/high impacts, an evaluation of shrimp farm size classes by zone, and surface area was conducted (see Table 5). The following assumptions were made for this evaluation: 1) impact categories are: low impacts are <100 ha and medium and high impacts are >100 ha, and 2) the Habitat criterion evaluates the impact across the landscape due to shrimp farming, therefore the surface area is the most appropriate metric to evaluate for farm size class impact instead of the number of farms within each size class.

Incorporating these assumptions finds that in the beaches and bays: the majority of farm surface area, roughly 65%, operating in beaches and bays are less than 100 ha in size and would qualify as having to apply for environmental licensing, while 35% are greater than 100 ha and would undergo the environmental registry process. For highlands, roughly 31% of the farm surface area would qualify as a low impact operation while the majority, 69%, would qualify as a medium-high impact operation and would undergo the environmental registry process. Altogether, 41% of the total surface area in Ecuador would qualify as low impact (<100 ha) and qualify for environmental registry, while 59% is considered medium-high impact (>100 ha) and would be required to seek an environmental license.

However, it is unclear when (date) new farms were sited, when the regulations which require EIAs and EMPs were passed and if they were retroactive. Some evidence suggests that EIAs and EMPs were required at least as of 2014 (SFW, 2014), but whether this applies to all shrimp farms from the past is unknown. Therefore limitations are apparent, as it is unclear how many farms that qualify as being medium, to high impact have gone through the environmental registry pre farm siting process.

Table 5: The number of farms and the surface area of shrimp farms by size range. Source: Subsecretary of Aquaculture, 2020.

Size Range	**Beaches and Bays**		**Highlands**		**Total**	
	Number of Farms	Surface Area	Number of Farms	Surface Area	Number of Farms	Surface Area
0-10	762	5,099.75	639	12,566.76	1401	17,666.51
10 to 20	414	5,989.03	283	4,158.62	697	10,147.65
20 to 30	250	6,155.06	186	4,648.17	436	10,803.23
30 to 40	152	5,279.37	115	3,957.30	267	9,236.67
40 to 50	145	6,535.07	108	4,813.93	253	11,349.00
50 to 100	201	14,452.38	213	15,450.90	414	29,903.28
100 to 250	120	19,839.11	206	32,750.57	326	52,589.68
250 to 500	13	4,103.39	78	25,943.31	91	30,046.70
500 to 1000			31	20,971.78	31	20,971.78
1000 to 2000			17	23,896.41	17	23,896.41
Total	20157	67453.16	1876	149157.8	3922	216,610.91

Regardless of the farm siting process or farm size, it is illegal for farms to convert mangrove forests. All farms are sited in what is technically considered beaches and bays, and highlands (as discussed in section 3.1). However, these zones are fundamentally connected habitat areas, and there are no management measures that take this, or the cumulative impact of farms being sited in these habitats, into account.

In the past, legislation and legal instruments were ineffective at protecting mangrove and estuarine habitat as shrimp farm expansion rates increased from 1970 to 1995 despite legal protections existing (Bietl, 2016; Hamilton, 2019). According to Bietl (2016), this was due to the bureaucratic and legal loopholes that existed since the beginning of the shrimp farming industry in 1970 up to 1995, when mangrove forest legislation was given further specificity and conferred greated protection with the passing of Decree 3327. Following its passing, many environmental protections and legal frameworks were created and implemented that strengthened environmental protections: (Bietl, 2016)

- **Ministerial Agreement 172 in 2000** “Provides the legal basis for authorizing the agreements to communities and “ancestral users” for the sustainable use and conservation of mangroves.”

- **Executive Decree 3198 in 2002** "Regulates all activities related to breeding and cultivation of bioaquatic species."
- **Executive Decree 3516 in 2003** "Establishes basic environmental policy in Ecuador including the protection and conservation of mangroves, prohibiting all exploitation and cutting and acknowledges ancestral communities in mangrove conservation."
- **Amendment to the Forestry Law of 2004** "penalties for infractions of the law, such as cutting, burning, transforming, altering, utilizing, commercializing or transporting mangroves."
- **Amendment to the Constitution: Rights of Nature** "Nature, or Pacha Mama, where life is reproduced and occurs, has the right to integral respect for its existence and for the maintenance and regeneration of its life cycles, structure, functions, and evolutionary processes. All persons, communities, peoples, and nations can call upon public authorities to enforce the rights of nature. To enforce and interpret these rights, the principles set forth in the Constitution shall be observed, as appropriate."
- **Decree 1391 in 2008:** "This decree calls to regulate the shrimp industry, holding those who have illegally occupied mangrove areas accountable"

These legal instruments helped to stem the conversion of estuary ecosystems to shrimp farms, mandated reforestation of mangroves, and empowered ancestral users as managers of mangrove forests. The passing of Decree 1391 in 2008 required farmers to reforest a percentage of their farm area if the farm was built (illegally) after 1995 when Executive Decree 3327 Regulation for the Management, Conservation and Use of Mangroves was passed. The amount of mangroves to be reforested was dependent on the size of the farm: (Bietl, 2016)

- Less than 10 hectares, 10% of farm area must be reforested
- Less than 50 hectares, 20% of farm area must be reforested
- Less than 250 hectares, 30% of farm area must be reforested

According to the Ministry of Environment (2019), 1,367 farms were a part of the concession process with 4,267.63 ha estimated for mangrove reforestation. As of April 2019, Ecuador has reforested 3,121.93 hectares of mangroves since 2009 hectares (see Table 6) (Undersecretary of Marine and Coastal Management, 2019).

The Rights of Nature Act (2008) helped to strengthen ancestral users rights that were originally recognized in 1999 with Ministerial Agreement 172. With this agreement "the government officially recognized the rights of ancestral communities or user groups to exercise a form of collective property rights to marine resources through government–community concession agreements called Acuerdos de Uso Sustentable y Custodia del Manglar (custodias). Since 2000, the Ministry of Environment has authorized ten-year concessions to over 50 local associations and cooperatives composed primarily of artisanal fishers. Over 40 percent of the country's remaining mangroves are now protected by these co-management arrangements designed to promote decentralized conservation and sustainable use." (Bietl, 2016).

Table 6: Mangrove Restoration in Ecuador by Province as of 2019. (Undersecretary of Marine and Coastal Management, 2019).

Province	Restored Mangroves (ha)
Esmeralda	153.71
Manabi	219.03
Santa Elana	0.94
Guayas	1,902.50
El Oro	845.75
Total	3,121.93

Overall, the management system is limited. Since 1999, all new farms and farm expansions are occurring in the highlands where 69% of the surface area is classified as medium to high impact. Medium to high impact projects must undergo the environmental license process, which means they are sited according to ecological principles by requiring Environmental Impact Assessments and Environment Management Plans. The remaining 31% of highland operations are considered low impact and undergo an environmental registry process, which does not require an EIA or EMP for project development but must comply with all legislation and regulations for aquaculture production. If considering all farming zones (beaches and bays and highlands), roughly 41% of total farm surface area in Ecuador qualifies as low impact with farms sizes less than 100 ha. Thus, there are apparent limitations to this habitat management system. It is unclear when (what year) new farms were sited, when the regulations which require EIAs and EMPs were passed and if they were retroactive. Furthermore, the management measures have focused on protecting the estuaries, while allowing for ongoing development of the estuary edge (see Factor 3.1) with no apparent growth restrictions. As a result, the connectivity of these ecosystems, and the cumulative impact of farms being sited along the estuary edge has not been taken into account within the management measures.

Therefore, the management system does require most farms to be sited according to ecological principles and/or environmental considerations, but does not account for habitat connectivity and cumulative impacts on ecosystem services. As a result, the Final score for Factor 3.2a is 2 out of 5.

Factor 3.2b: Enforcement of habitat management measures

The Ministry of Environment's Undersecretary of Environmental Quality and Natural Patrimony, and the Vice Ministry of Aquaculture and Fisheries Undersecretary of Aquaculture, the Undersecretary of Marine and Coastal Management and custodias oversee aquaculture activities, the enforcement of environmental standards and monitoring of mangrove forests (Vega and Beillard, 2015; Ministry of the Environment, 2020; Ministry of Production, International Trade, Investment and Fisheries, 2020; Organic Environment Code, 2018). There are six aquaculture inspector offices throughout Ecuador's coastline (2 in El Oro, 1 in Guayas, 2 in Manabi, and 1 in Esmeraldas) (Vice Ministry of Aquaculture and Fisheries, 2020). The number of employees is not publicly available. Custodias are also enforcement organizations that help to ensure sustainable use of mangrove forests.

Government audits are the primary tool for monitoring and enforcing compliance with regulations. Farms are audited once within the first year of operation and then once every three years by the competent authority from the Ministry of Environment and/or the Vice Ministry of Aquaculture and Fisheries (Organic Environment Code, 2018; personal communication Higa, 2020; personal communication Piedrahita, 2020). Before arriving, the competent authority communicates with the farm to ensure that the technical staff are present during the audit (personal communication Higa, 2020). Relevant metrics for compliance during the audit process for the Habitat criterion includes evaluating farm boundaries to ensure no unauthorized construction has taken place (personal communication CNA, 2020).

Failure to comply with regulations and practices described in the environmental impact assessments or environmental management plans may result in a fine, imprisonment, or even both depending on the severity of the offense. For example, ecosystem damages and/or impacts resulting from prohibited chemicals, organic pollutants, diseases, may result in imprisonment from up to 5 years (Organic Environment Code, 2018) and falsifying or concealing information to the Ministry of Environment may result in imprisonment from 1 to 3 years (Organic Environment Code, 2018). Records or other evidence of compliance with environmental regulations are not made public (personal communication, CNA, 2020)

Custodias help to manage, protect and ensure that mangrove ecosystems are being used sustainably. To become a custodias, ancestral users go through a formal process with the Ecuadorian government that, ultimately, acknowledges a custodias as protectors or guardians of the mangrove and estuary (Bietl, 2016). This co-management designation now protects 40% of Ecuador’s mangroves from illegal extraction of mangroves and estuary resources (Bietl, 2016).

Since the passing of Rights of Nature and Decree 1391, 3,121.63 hectares of mangrove forests have been reforested out of 4,267.63 hectares (Undersecretary of Marine and Coastal Management, 2019). The reforestation efforts are managed and monitored by the Undersecretary of Marine and Coastal Management in accordance to Decree 1391. Not all mangrove reforestation are able to be replanted in the original deforested location, so offsets in other coastal locations/provinces are done as approved by the Undersecretary of Marine and Coastal Management (Undersecretary of Marine and Coastal Management, 2019).

Overall, enforcement of habitat management measures is moderate. The enforcement organizations - Ministry of Environment’s Undersecretary of Environmental Quality and Natural Patrimony, and the Vice Ministry of Aquaculture and Fisheries Undersecretary of Aquaculture and the Undersecretary of Marine and Coastal Management and custodias - are identifiable and contactable. The size and scale of these agencies and co-management groups are not well understood, so it is challenging to determine whether they are able to effectively manage the environmental regulations and habitat measures outlined. Historically, as suggested with Decree 1391, illegally operating farms was a reality even though mangrove protections existed, but since 1999 no new development has occurred in mangrove forests (see Factor 3.1) and concessions were made in 2008. This suggests that enforcement and governance has effectively stopped any and all illegal shrimp farming operations and deforestation of mangrove habitat. The main tool to monitor compliance and enforcement to regulation is the farm siting process and the ensuing audits. The farm siting process does appear to have enforcement limitations as farms that are determined to be low impact are not as rigorously vetted prior to aquaculture production. Low impact farms account for roughly, 31% of the shrimp farming surface area in the highlands, which is where all shrimp farming development or expansion has occurred since 1999. However, all farms, regardless of the classification of their impact must comply with pertinent environmental regulations, which are enforced through onsite audits. These audits are conducted once within the first year of operation, and then once every three years. The results of these audits are not made public. As a result, there are limitations that reduce the effectiveness of habitat enforcement. Therefore, the score for Factor 3.2b is 3 out of 5.

The final score for Factor 3.2 is a combination of Factor 3.2a (3 out of 5) and Factor 3.2b (3 out of 5), and results in a score of 3.6 out of 10.

Conclusions and Final Score

Significant conversion of estuary habitat to shrimp farms occurred prior to 1999 in Ecuador as mangroves and estuaries were the preferred location for shrimp farm development. Since 1999, new development of dry shrub habitat, highlands, along the estuary edge is ongoing. In total, the shrimp farming industry has increased by 41,357.39 ha since 1999 with all expansion occurring outside of the estuary along the estuary edge. Over the past 3 years, 6,334.98 ha of habitat along the estuary edge has been converted to shrimp farming area. Considering that the estuary and the estuary edge (dry shrub habitat) are fundamentally connected habitats, the significant expansion of shrimp farms into the estuary edge since 1999 has extended the impacts of the shrimp farming industry from within the estuary to the estuary edge. Therefore, considering the historic loss of functionality in the broader estuarine ecosystem, recent marginal conversion on the estuary edge is not considered to represent ongoing loss of functionality in the estuary and the final score is 4 out of 10. The management system does require most farms to be sited according to ecological principles and/or environmental considerations, but there are limited considerations of cumulative habitat impacts and loss of ecosystem services. As a result, the Final score for Factor 3.2a is 2 out of 5. These management measures are enforced by organizations that are identifiable and contactable. The size and scale of these agencies and co-management groups are not well understood, so it is challenging to determine whether they are able to effectively manage the environmental regulations and habitat measures outlined. About 31% of shrimp farms are considered low impact and are operating in the highlands, where all new development has occurred since 1999. Low impact farms are not as rigorously vetted prior to aquaculture production as medium and high impact farms, which are required to be sited with EMP and EIA. As a result, there are limitations that reduce the effectiveness of habitat enforcement. Therefore, the score for Factor 3.2b is 3 out of 5.

The score for Criterion 3 – Habitat is a combination of the scores for Factor 3.1 – Habitat conversion and function (4 out of 10) and Factor 3.2 – Farm siting regulation and management (2.40 out of 10), and the final score is 3.47 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

Chemical Use parameters	Score	
C4 Chemical Use Score (0-10)	**3**	
Critical?	NO	**RED**

Brief Summary

Overall, chemical use in Ecuadorian shrimp aquaculture is common, though most do not pose significant environmental concerns. The chemicals used for pond preparation in Ecuadorian shrimp farming pose a low risk to the environment, given the rapid degradation of these compounds and their byproducts. On the other hand, the use of antibiotics in aquaculture can result in the development of antibiotic-resistant bacteria in the environment and pose significant risks to both the environment and human health. There are effective regulations that limit the type of antibiotics available and its use is enforced, so that harvested shrimp are compliant to any residue requirements. The frequency of antibiotic use appears limited for larger farms as alternative treatments are sought. Ongoing development to address research gaps, monitor antimicrobial resistance, and increase technical control and barriers for the access and usage of antibiotics is being addressed. This collaborative working group is being led by Ecuador's agricultural stakeholders and the United Nations Food and Agriculture Organization. Results from this working group would likely help to greatly improve data availability, transparency, and understanding of the amount of antibiotics in use, as well as increase the barriers for farmers in obtaining antibiotics.

Combined, the effective governance and low use suggests a score of a 4 out of 10 for chemical use. On the other hand, data were not available to robustly estimate the frequency and total volume of antibiotic application, though antibiotic use is known to occur. Small and mid-size farms are more likely to use antibiotics, and the frequency of use may be multiple times per production cycle. Therefore, it is concluded that antibiotics that are highly important for human medicine are used in unknown quantities, which warrants a score of a 2 out of 10. Given this, an intermediate score is justified and the final score for Criterion 4 – Chemical Use is 3 out of 10.

Justification of Rating

A variety of chemicals may be used on shrimp farms to address issues such as water quality or disease, and while the acute environmental impact of on-farm chemical use is often unknown, "chemicals, disinfectants, pesticides and antibiotics have been shown to be the most environmentally hazardous compounds owing to their high toxicity to non-target organisms and/or potential for bioaccumulation over tropic chains, and can potentially affect the biodiversity and functioning of adjacent aquatic ecosystems." (Rico et al. 2012).

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

Detailed information regarding chemical use on shrimp farms in Ecuador is somewhat limited. Some understanding of current usage could be obtained from literature and personal communications, yet information regarding the total quantity and application frequency of chemicals was scarce. Chemicals used include pond preparation agents, such as lime, disinfectants, and veterinary medications, such as antibiotics.

Antibiotics

Ecuadorian regulations allow for the use of certain antibiotics and is overseen by the Undersecretary of Quality and Safety (SCI) of the Ministry of Aquaculture and Fisheries. The SCI's "objective is to maintain the sanitary guarantees of products and by-products of fishing and aquaculture by increasing in situ control and increasing the frequency of verification to suppliers of materials raw materials and inputs for aquaculture use." The General Regulation to the Fisheries and Fisheries Development Law, and the Organic Code of Environment are the legislative tools that help to manage the use of antibiotics on the farm, which is audited according to the prescriptive measures of the National Control Plan. The National Control Plan establishes the "control of prohibited substances, and use of medications and pharmacological substances for application in aquaculture, misuse of authorized veterinary products for application in aquaculture, control of importing establishments, distributors and retail sale of veterinary products for aquaculture use, and application of appropriate measures in order to minimize the appearance of residues in finished aquaculture products." (National Control Plan, 2015).

According to the Undersecretary of Quality and Food Safety (SCI), there are more than 500 chemical products that are authorized for use in Ecuador aquaculture production.[5] From 2015-2017, "32 antibiotic products were registered, 21 were imported, and 11 are processed products national[ly] with active principle of authorized antibiotics." (Vice Ministry of Aquaculture and Fisheries, 2017). Oxytetracycline was the most imported antibiotic with imports increasing from 25,386 kg to 84,615 kg in 2015 and 2017, respectively (see Figure 7).

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[5] As of July 15, 2020 a pdf list of authorized products can be found here: http://acuaculturaypesca.gob.ec/wp-content/uploads/2020/07/RSU-15-JULIO-2020-Vigentes-P23072020.pdf

Florfenicol was the second most imported antibiotic with 10,500 kg imported in 2015 and 32,200 kg imported in 2017 (Vice Ministry of Aquaculture and Fisheries, 2017). Enrofloxacin was also imported from 2015-2017, with import quantities of 1,300 and 1,450, respectively. Since 2018, enrofloxacin has been banned for aquaculture use in Ecuador (IntraFish, 2019), but oxytetracycline, and florfenicol are still allowed (Ministry of Aquaculture and Fisheries, 2018; Regulation to the Fisheries and Fisheries Development Law Title VI, Chapter 1, Article 139; Vice

Ministry of Aquaculture and Fisheries, 2017). Both florfenicol and oxytetracycline are designated by the World Health Organization as highly important antimicrobial drugs for human medicine (WHO, 2019).

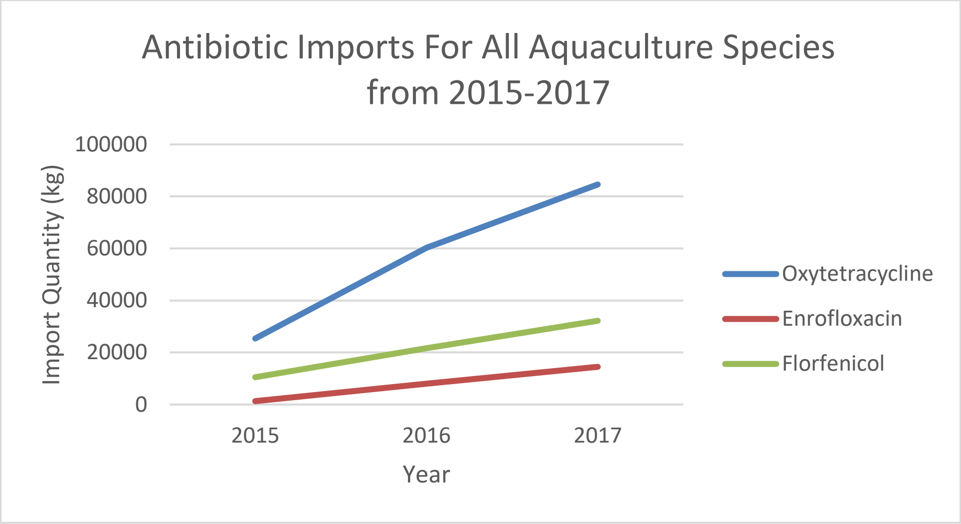

Figure 7: Ecuadorian antibiotic imports from 2015 to 2017. Antibiotics include oxytetracycline, enrofloxacin, and florfenicol. In 2018, enrofloxacin was banned in Ecuador. Source: FAO, 2019.

If symptoms are observed, they are typically seen in the first 30-45 days of being transferred to grow out ponds when bacteria, such as vibriosis, can proliferate due to an increase in stress as a result of physical and environmental change (see Disease Criterion). The risk of infection is correlated with changes in the season, when pond water temperature can become colder or hotter than average temperatures (personal communication Higa, 2020; personal communication CNA, 2020).

Following observed symptoms, some larger farms have the resources to investigate potential bacterial, or viral infections through plate culture, antibiogram, and/or Minimal Inhibitory Concentration (MIC) analysis at internal laboratories, and depending on the results, take corrective action (personal communication, CNA, 2020). Farms that do not have access to their own laboratories may consult with their feed manufacturer/supplier, which generally have technicians with backgrounds in "biology, veterinary or aquaculture sciences" who frequently visit customers, help monitor shrimp health, and recommend management strategies (personal communication, CNA, 2020).

Following a diagnosis, the decision to apply antibiotic treatment is determined by the farmer/management staff. If antibiotics are used, they are mixed into the feed. Application instructions are required to be present on all products in order to be authorized for sale in Ecuador (Vice Ministry of Aquaculture and Fisheries, 2020; Vice Ministry of Aquaculture and Fisheries, 2017). And they must include information about the dosage amount as well as the associated withdrawal time required to comply with the maximum residue limits set by international laws, markets, and domestic legislation (Vice Ministry of Aquaculture and Fisheries, 2017). When applying antibiotics, farmers will reduce the daily water exchange from 8% to zero to maximize the application effectiveness (personal communication CNA, 2020). It is unclear how long the discharge is modified, but it is likely that the resumption of regular exchange of water occurs immediately after treatment is concluded.

If a farm does use antibiotics, typically the frequency is once per production cycle and is usually only used if other chemical treatments (e.g. probiotics, organic acids, etc.) are unsuccessful at mitigating the issue (personal communication CNA, 2020; Vice Ministry of Aquaculture and Fisheries, 2017). Oxytetracycline and/or florfenicol may be applied for 7 to 10 days, and the typical withdrawal period is 12 to 18 days after application (Vice Ministry of Aquaculture and Fisheries, 2017).

Generally, small and medium sized farms are more likely to apply antibiotics but can depend on the region, while larger farms utilize alternative approaches (e.g. probiotics, organic acids, garlic etc.) and apply antibiotics less frequently (personal communication Anonymous, 2020). Small and medium sized farms are characterized as those less than 250 ha (personal communication Corsin and van Wageningen, 2020), which equates to roughly 65% of the total shrimp farming surface area in Ecuador, or 96% of the number of farms in Ecuador (see Table 7). Using the estimated average of 2.93 mt/ha, the estimated amount of production that is more likely to use antibiotics in 2019 is 65% or 415,169.34 mt.

Table 7: The number of farms and the surface area of shrimp farms by size range.

Size Range	Beaches and Bays		Highlands		Total	
	Number of Farms	Surface Area	Number of Farms	Surface Area	Number of Farms	Surface Area
0-10	762	5,099.75	639	12,566.76	1401	17,666.51
10 to 20	414	5,989.03	283	4,158.62	697	10,147.65
20 to 30	250	6,155.06	186	4,648.17	436	10,803.23
30 to 40	152	5,279.37	115	3,957.30	267	9,236.67
40 to 50	145	6,535.07	108	4,813.93	253	11,349.00
50 to 100	201	14,452.38	213	15,450.90	414	29,903.28
100 to 250	120	19,839.11	206	32,750.57	326	52,589.68
250 to 500	13	4,103.39	78	25,943.31	91	30,046.70
500 to 1000			31	20,971.78	31	20,971.78
1000 to 2000			17	23,896.41	17	23,896.41
Total	20157	67453.16	1876	149157.8	3922	216,610.91

The control of antibiotic application is monitored through audits, and by testing the residue of harvested shrimp. Random onsite inspections occur on farms at least once a year by the Undersecretary of Quality and Safety (SCI) of the Ministry of Aquaculture and Fisheries to assess compliance to the National Control Plan. This onsite inspection is separate from the Ministry of Environments onsite inspections, which happen randomly within the first year of operation and then once every three years after to ensure compliance to the environmental management plan. The SCI inspections help to assure the safety of food products and evaluates the farms compliance with antibiotic or veterinary drug use regulation as prescribed in the National Control Plan (NCP). The inspection evaluates any chemical products present to make sure they are legal, farm documentation of any veterinary drug application, and if veterinary drugs have been applied, compliance with label use and that there is sufficient withdrawal time so that when the shrimp are harvested the maximum residue limit is not exceeded (National Control Plan, 2015). All export products must be in compliance with trading partner requirements, so to further ensure that residue limits are not exceeded, all harvested shrimp batches are evaluated for antibiotic residue at the processing center (personal communication CNA, 2020). As a result, over the past 10 years, there have been no import rejections by the United States or the EU for Ecuadorian shrimp due to veterinary drug residue issues (RASFF, 2020; USFDA, 2020).

Although Ecuadorian shrimp production systems are relatively open with a daily water exchange rate of 8%, there is limited research and information on whether antibiotic use on shrimp farms is linked or causing bacterial resistance outside of farms. According to Sperling et al. (2015), shrimp samples collected from farms in Ecuador showed evidence of bacterial resistance in varying degrees to highly and critically important antimicrobials for human medicine (World Health Organization, 2018): ampicillin, tetracycline, amikacin, and gentamicin. Additionally, the authors noted multidrug resistance in 76% of the most prevalent *Vibrio* strain isolated (*V. parahaemolyticus*). Unfortunately, it is not possible to determine whether the resistant bacteria entered shrimp farms through water exchanges, or if excessive use of antibiotics on shrimp farms contributed selective pressure towards the development of resistance; it is noteworthy, however, that the studied bacteria exhibited resistance to antibiotics that are not known to be used in shrimp culture in Ecuador. In a separate study, oxytetracycline and ampicillin resistance was observed in *Vibrio* strains isolated from hatchery shrimp in Ecuador and the author notes that the oxytetracycline resistance may be due to its prolonged use at shrimp hatcheries, but could also be due to anthropogenic activity in the area of the hatchery, as ampicillin is again not known to be used in shrimp culture (Sotomayor et al. 2019).

Efforts are currently underway to address antibiotic usage by shrimp farmers in Ecuador. Two key stakeholder processes have begun; the creation and development of the Sustainable Shrimp Partnership (SSP) and the United Nations Food and Agriculture Organizations engagement with the Ecuador government and agriculture stakeholders to develop a National Action Plan for the ""Containment of the Antimicrobial resistance in terrestrial and aquatic food production systems under the One Health approach" (FAO, 2020).

The Sustainable Shrimp Partnership (SSP) was created in 2018 by a group of Ecuadorian shrimp companies. The mission of SSP is "to drive the future of shrimp aquaculture to be a clean, sustainable, and successful practice for the world." (SSP, 2020). All SSP shrimp are verifiably ASC-certified, use zero antibiotics, and are fully traceable utilizing IBM Food Trust blockchain technology (SSP, 2020). In 2020, there are "12 farms that represent around 11,000 ha" that are compliant members of the SSP (personal communication Piedrahita, 2020). The program looks to expand in the near future "With the support and guidance of the SSP Advisory Board – IDH The Sustainable Trade Initiative, World Wildlife Fund (WWF), and the Aquaculture Stewardship Council (ASC) – SSP developed the Scale-up programme. Its objective is to spread the word and work with small and mid-sized farms to improve their sustainability performance, and work towards achieving ASC certification and SSP product qualification criteria." (personal communication Piedrahita, 2020).

The United Nations Food and Agriculture Organization recently began engaging with Ecuador and its agricultural stakeholders to address antibiotic use and its potential impacts to human health. The program has developed a National Action Plan for the "Containment of the Antimicrobial resistance in terrestrial and aquatic food production systems under the One Health approach" (FAO, 2020). Results from this working group would likely help to greatly improve data availability, transparency, and understanding of the amount of antibiotics in use, as well as increase the barriers for farmers in obtaining antibiotics.

Given this information, it appears that concern for antibiotic chemical use is moderate to high. Oxytetracycline and florfenicol are both allowed for use by shrimp farmers in Ecuador and are both are designated by the World Health Organization as highly important antimicrobial drugs for human medicine. There is effective enforcement of regulations that require proper label use and record keeping of antibiotics applied on farm, as well as regular auditing of farms that includes testing for antibiotic residues in shrimp during the culture period and at harvest. This effort has been effective at ensuring that all shrimp exported are free of antibiotic residue or within the allowable limits imposed by international markets. However, these control strategies do not necessarily limit the use, or frequency of use, of antibiotics. Some evidence suggests that small and medium size farms are more likely to use antibiotics, which account for roughly 65% of the total shrimp farming surface area in Ecuador, or 96% of the number of farms in Ecuador. The frequency of application appears to be typically once per production cycle. Further detailed information on whether this application frequency is the exception, or if antimicrobial resistance (AMR) is occurring in part due to shrimp farming activities is not available. Ongoing development to address these research gaps, monitor AMR, and increase technical control and barriers for the access and usage of antibiotics is being addressed by the collaborative work between Ecuador agriculture stakeholders and the United Nations Food and Agriculture Organization. The pending implementation of recommendations coming from this collaboration and resulting studies would help to greatly inform the risk of antibiotics by shrimp farmers in Ecuador, beyond what is currently available. However, the information at present demonstrates that antimicrobials highly important for human medicine are being used, but it is unknown if it is being used in significant quantities (considered by Seafood Watch as more than once per production cycle).

Pond preparation, disinfectants, and piscicides

A variety of other chemicals are used in the Ecuadorian shrimp farming industry, largely to create optimal pond water quality conditions. Chemical treatments are used in three phases of the production cycle: prior to stocking, during grow out, and at harvest.

Prior to stocking, herbicides and pesticides like fluoride, organic acids, and calcium carbonate have been known to be applied to ponds to remove unwanted vegetation and pest organisms (Hamilton, 2019); the use of these is not considered a risk to the environment. During grow out, to help promote healthy growing conditions and immune systems, organic acids, probiotics, and essential oils all are used and adoption has increased in recent years (Lucien-Brun, 2017; Sotomayor et al., 2019; personal communication Higa, 2020; personal communication Piedrahita, 2020). The impact these treatments may have downstream is regulated by the maximum daily discharge set by the Ministry of Environment, which limits the amount of organophosphates and organochlorines exiting shrimp farms to 100 mg/l and 50 mg/l respectively (Unified Secondary Legislation of the Ministry of the Environment: Environmental Quality and Discharge of Effluents to Water Resources); however as stated previously, audit frequency and the robustness of enforcement appears to be somewhat limited (see Criterion 2 – Effluent).

During harvest for head on shell on shrimp products, shrimp are harvested from ponds and dipped into a bath of an antioxidant solution of sodium metabisulphite, packed in ice and then transported to the processing centers to be frozen and exported (personal communication Leonard, 2020; Lucien-Brun, 2016; Bermudez-Medranda and Panta-Velez, 2019). It has been reported that the sodium metabisulphite solution is sometimes discharged directly into the surrounding watershed (personal communication Higa, 2020), but more commonly it is treated with calcium carbonate before discharging to neutralize its effects on receiving waters (personal communication Gonzalez, 2020). Depending on the discharge concentration, metabisulphite can lower the pH and create hypoxic conditions to its surroundings, which can negatively impact flora and fauna (Portillo et al, 2014; I.M. da Costa Machodo Motas Carvalho et al. 2010).

Conclusions and Final Score

Overall, chemical use in Ecuadorian shrimp aquaculture is common, though most do not pose significant environmental concerns. The chemicals used for pond preparation in Ecuadorian shrimp farming pose a low risk to the environment, given the rapid degradation of these compounds and their byproducts. On the other hand, the use of antibiotics in aquaculture can result in the development of antibiotic-resistant bacteria in the environment and pose significant risks to both the environment and human health. There are effective regulations that limit the type of antibiotics available and its use is enforced, so that harvested shrimp are compliant to any residue requirements. The frequency of antibiotic use appears limited for larger farms as alternative treatments are sought. Ongoing development to address research gaps, monitor antimicrobial resistance, and increase technical control and barriers for the access and usage of antibiotics is being addressed. This collaborative working group is being led by Ecuador’s agricultural stakeholders and the United Nations Food and Agriculture Organization. Results from this working group would likely help to greatly improve data availability, transparency, and understanding of the amount of antibiotics in use, as well as increase the barriers for farmers in obtaining antibiotics.

Combined, the effective governance and low use suggests a score of a 4 out of 10 for chemical use. On the other hand, data were not available to robustly estimate the frequency and total volume of antibiotic application, though antibiotic use is known to occur. Small and mid-size farms are more likely to use antibiotics, and the frequency of use may be multiple times per production cycle. Therefore, it is concluded that antibiotics that are highly important for human medicine are used in unknown quantities, which warrants a score of a 2 out of 10. Given this, an intermediate score is justified and the final score for Criterion 4 – Chemical Use is 3 out of 10.

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

C5 Feed parameters	**Value**	**Score**
F5.1a Forage Fish Efficiency Ratio	0.735	
F5.1b Source fishery sustainability score (0-10)		6
F5.1: Wild fish use score (0-10)		7
F5.2a Protein INPUT (kg/100 kg fish harvested)	49.135	
F5.2b Protein OUT (kg/100 kg fish harvested)	17.8	
F5.2: Net Protein Gain or Loss (%)	-63.773	3
F5.3: Species-specific kg CO2-eq kg^{-1} farmed seafood protein	21.045	5
C5 Feed Final Score (0-10)		5.50
Critical?	No	Yellow

Brief Summary

In Ecuador, feed for whiteleg shrimp use fishmeal and fish oil that is made from whole wild fish and from byproduct sources. The fishmeal inclusion level is 20.62% and the fish oil inclusion level is 1.6%; with 47.05% of fishmeal and 31.25% of fish oil sourced from byproducts from the Ecuadorian tuna purse seine fishery, and the remaining 52.95% of fishmeal and 68.75% of fish oil originating from whole fish from the Ecuadorian forage fish purse seine fishery. The Forage Fish Efficiency Ratio (FFER) is low (0.786), meaning that 0.786 mt of wild fish are needed to produce the fishmeal required to produce one mt of farmed shrimp. The sustainability of the source fisheries is moderate and scores a 6 out of 10. Combined with a low FFER, the Factor 5.1 - Wild fish use score is a 7 out of 10. The net protein loss of -63.77% is high and results in score of 3 out of 10 for Factor 5.2 – Net protein gain or loss. The feed footprint is moderate with approximately 20.95 kg of CO_2-eq per kg of harvested protein, resulting in a score of 5 out of 10 for Factor 5.3 – Feed footprint. Altogether, the three factors combine to give a final score of 5.50 out of 10 for Criterion 5 -Feed.

Justification of Rating

In Ecuador, shrimp are farmed under semi-intensive conditions that depend on the use of commercial pelleted feed in addition to primary productivity in ponds, which is typically stimulated with fertilizer input.

Data used to inform this criterion were obtained from Skretting, one of the largest feed manufacturers in Ecuador (Mereghetti, 2017; personal communication Gonzalez, 2020), as well as from the primary literature and publicly-available Aquaculture Stewardship Council (ASC) audits. Combined, this information is considered broadly representative of a typical shrimp feed used in Ecuador.

The Seafood Watch Aquaculture Standard assesses three feed-related factors: wild fish use (including the sustainability of the source), net protein gain or loss, and the feed "footprint" or embedded global warming potential of ingredients in feed required to produce one kg of farmed shrimp protein.

Factor 5.1. Wild Fish Use

Factor 5.1 combines an estimate of the amount of wild fish used to produce farmed whiteleg shrimp with a measure of the sustainability of the source fisheries. Table 9 shows the data used and the calculated Feed Fish Efficiency Ratio (FFER) for fishmeal and fish oil.

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

The Feed Fish Efficiency Ratio (FFER) for aquaculture systems is driven by the feed conversion ratio (FCR), the amount of fish used in feeds, and the source of the marine ingredients (i.e., does the fishmeal and fish oil come from processing byproducts or 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.

The use of a single eFCR value to represent an entire industry is challenging. The difficulty is rooted in the differences in shrimp genetics, feed formulations, farm practices, occurrence of disease, and more. After reviewing available data, an industry average eFCR of 1.55 is considered representative of Ecuadorian whiteleg shrimp production (personal communication Massaut; personal communication Higa, 2020; ASC, 2019; Lucien-Brun, 2017; SFW, 2014; Hasan and Soto, 2017; Molina and Espinoza, 2018; Vega and Beillard, 2015; Starostina, L., 2016; Skretting, 2016).

Data regarding ingredient composition were gathered from multiple sources including a feed manufacturer (Skretting, personal communication, 2020), and Aquaculture Stewardship Council (ASC) certification audits of Ecuadorian shrimp farms.

There is considerable variation in the ingredient composition of Ecuador shrimp feeds, as demonstrated by a diversity of published reports noting a number of different ingredients used in feeds, with total fishmeal (FM) and fish oil (FO) inclusions ranging from 4.0- 42.0% and 0.0-5.0%, respectively (see Table 8). In total, there were 28 data points for fishmeal inclusions and 28 data points for fish oil inclusions (see Table 8). To calculate representative inclusion levels for fishmeal and fish oil, several assumptions were made. As numerous sources were used, a weighted average was applied. According to Seafood Watch, 10% of all Ecuador whiteleg shrimp production is currently certified by ASC, therefore a weighted average of 10% was applied to all ASC values, and 90% weighted average was applied to all other sources. The resulting fish meal inclusion level is 20.62% and total fish oil inclusion level is 1.6% and summarized in Table 8.

Table 8 Weighted average, range of reported values and the number and source of values generated for key data points to determine the Feed Fish Efficiency Ratio.

Parameter	Weighted Average	Min	Max	Number of Data Points[1]	ASC Data Points[2]
Total Fishmeal Inclusion Level	20.62%	4.0%	20.9%	28	27
Total Fish Oil Inclusion Level	1.6%	1.0%	5.0%	28	27
Byproduct Fishmeal inclusion level	9.7%	*NA*	15.0%	1	0
Byproduct Fish Oil inclusion level	1.6%	1.6%	*NA*	1	0

[1] The number of sources is the total of the cited values from ASC reports, Research Reports and Skretting

[2] There are 15 total reports used: Omarsa, Santa Priscila, COFIMAR, CALADEMAR, GRUPACIF, Agricola y Psicola Carolin S.A., CIPRON C Ltda, PROMARISCO, Terraquil, and SONGA. The fish meal and fish oil inclusion levels cited from these reports are from VitaPro, Skretting, INPROSA, Biomar, Nicovita, Molinos Champion, Agripac and Cargill feed companies.

The use of byproducts in shrimp feeds, as with other ingredients, varies by formulation and feed manufacturer. Data for byproduct inclusion for FM and FO was gathered directly from a feed manufacturer in Ecuador and is the only source used for estimating byproduct inclusions. According to the manufacturer, roughly 47.05% of fishmeal used in Ecuadorian shrimp feed is sourced from byproducts – trimmings from IFFO-RS certified tuna processing plants/fisheries – while the remaining 52.95% is sourced from wholefish. For fish oil, roughly 31.25% of fish oil is sourced from byproducts, trimmings from IFFO-RS certified tuna processing plants/fisheries, while the remaining 68.75% comes from wholefish.

Table 9 Parameters used and their calculated values to determine the use of wild fish in feeding Ecuador farmed shrimp.

Parameter	Data
Fishmeal inclusion level (total)	**20.62 %**
Fishmeal inclusion level (whole fish)	10.92%

Fishmeal inclusion level (byproduct)	9.7%
Fishmeal yield	22.5%
Fish oil inclusion level (total)	**1.6%**
Fish oil inclusion level (whole fish)	1.1%
Fish oil inclusion level (byproduct)	0.5%
Fish oil yield	5.00%
Economic Feed Conversion Ratio (eFCR)	1.55
Calculated values	
Fish meal feed fish efficiency ratio (FFERfm)	0.786
Fish oil feed fish efficiency ratio (FFERfo)	0.349
Assessed FFER	**0.786**

The Feed Criterion considers the FFER from both fishmeal and fish oil and uses the higher of the two to determine the score. Fish meal and oil sourced from byproducts are partially included in the FFER calculation at a rate of 5% of the inclusion level(s), in order to recognize the ecological cost of their production; please see the Seafood Watch Aquaculture Standard for additional details. As seen in Table 9, the fishmeal inclusion level drives the FFER for Ecuador farmed shrimp; since 52.95% of the fishmeal used is from whole fish and 47.05% comes from byproducts, and 0.786 tons of wild fish are required to provide sufficient fishmeal to produce one ton of farmed shrimp.

Factor 5.1b – Sustainability of the Source of Wild Fish

The basic wild fish use score (Factor 5.1a) is adjusted based on the sustainability of the source fisheries of fishmeal and fish oil. Data regarding source fisheries in Skretting feeds were supplied by the company through personal communication, while attempts to gather fishmeal and fish oil source fishery data from other feed mills and scientific literature was unsuccessful. Therefore, the source fishery data provided by the feed company are considered representative of Ecuadorian shrimp feeds and used in this assessment. Fishmeal and fish oil originating from whole fish raw material were sourced from a variety of forage fish species, whereas fishmeal and fish oil from byproduct raw material were sourced from two tuna species. The FishSource scores and Seafood Watch ratings for each species (where applicable) are summarized in Table 10 for forage fish species and Table 11 for tuna species.

Table 10 Forage fish species and the sustainability scores and Seafood Watch Source Fishery Sustainability Score of each species fishing method. Country of origin is Ecuador.

	Method	**FishSource Stock Health***	**FishSource Future Stock Health**	**FishSource Mngmt Strategy**	**FishSource Mngmt Compliance**	**Seafood Watch Rting**	**Recent Stock Assessment Reference Points met? (Y/N)**	**Seafood Watch Source Fishery Sustainability Score**
Mackerel *Auxis Spp.*	Purse Seine	8.6	9.2	≥6	≥6	*NA*	Yes	8
Pacific anchoveta *Cetengraulis mysticetus*	Purse seine	<6	<6	<6	≥6	*NA*	Some	6
Largehead hairtail *Trichiurus lepturus*	Purse seine	<6	<6	<6	≥6	*NA*	Yes	8
Chub mackerel *Scomber japonicus*	Purse Seine	6.9	10	≥6	≥6	*NA*	Some	6
Mackerel scad *Decapterus macarellus*	Purse Seine	*UNK*	*UNK*	*UNK*	*UNK*	*NA*	*NA*	2
Longnose anchovy *Anchoa nasus*	Purse Seine	*UNK*	*UNK*	*UNK*	*UNK*	*NA*	*NA*	2
Red Eye round herring *Etrumeus acuminatus*	Purse seine	<6	<6	<6	≥6	*NA*	Some	6
Thread herring *Opisthonema spp.*	Purse seine	<6	<6	<6	≥6	*NA*	Yes	8
Avg Score for Forage Fish								**5.75**

* For references see Sustainable Fisheries Partnership in reference section

There are 8 forage fish species listed as a source for wholefish fishmeal and fish oil (*Auxis brachydorax, Cetengraulis mysticetus, Trichiurus lepturus, Scomber japonicus, Decapterus macarellus, Anchoa nasus, Etrumeus acuminatus,* and *Opisthonema spp.)* (see Table 10). The justification for the SFW source sustainability scores are as follows:

- The mackerel (*Auxis spp.*) FishSource scores are all ≥6 with a stock health score ≥8 and a future stock health score of 9.2, which results in a SFW source sustainability score of 8.
- Largehead hairtail (*Trichiurus lepturus*), and thread herring (*Opisthonema spp.*) both received a FishSource evaluation in 2019 with all scores <6 except for management compliance. However, after evaluating the most recent stock assessment by Canales et al. (2020), the biomass and fishing mortality reference points are met, so the SFW source sustainability score is an 8 for both largehead hairtail and thread herring.
- Red eye round herring and pacific anchoveta also received a FishSource evaluation in 2019 with all scores <6 except for management compliance. But an updated stock

assessment by Canales et al. (2020) determined that the stock biomass does not meet its reference biomass value of B_{40}, yet its fishing mortality is meeting its reference point; indicating the stock will recover and results in a source sustainability score of 6.

- The chub mackerel scores are all ≥6 with a stock health score of 6.9 and a future stock health score of 10, which results in a SFW source sustainability score of 6.
- The sustainability of the other forage fish species mackerel scad and longnose anchovy (*Decapterus macarellus* and *Anchoa nasus*) is unknown, which results in a source fishery sustainability score of 2.

The final source fishery sustainability score is the average of all forage fish species listed and is 5.75 (which is rounded to 6).

Table 11: Tuna species (Thunnus albacares and Katsuwomus pelamis) and the sustainability scores and Seafood Watch Source Fishery Sustainability Score of each species fishing method.

Genus Species	Method	FishSource Stock Health[1]	FishSource Mngmt Strategy	FishSource Future Heatlh	FishSource Mng Compliance	Fish Source Fishers Compliance	Seafood Watch Rating	IFFO Byproduct Approved[2]	Percentage of total catch[3]	Seafood Watch Source Fishery Sustainability Score
Yellowfin Tuna, *Thunnus albacares*	Purse Seining (FAD)	7	≥6	7.5	≥6	≥6	Red	Yes	28%	2
	Dolphin Set Purse Seine						Yellow	Yes	62%	6
	Unassociated purse seine (non-FAD)	7	≥6	7.5	≥6	≥6	Yellow	Yes	10%	6
Skipjack tuna, *Katsuwonus pelamis*	Dolphin set purse seining	≥8	≥6	≥8	≥6	≥6	Yellow	Yes	1%	6
	Unassociated purse seine (non-FAD)	≥8	≥6	≥8	≥6	≥6	Yellow	Yes	25%	6
	Purse Seining (FAD)	≥8	≥6	≥8	≥6	≥6	Red	Yes	74%	2
Weighted Avg. Score for Tuna										4.96

[1] FishSource for references see Sustainable Fisheries Partnership in reference section

[2] See IFFO Skipjack and Yellowfin reports in Reference section

[3] Percentage of total catch values are sourced from Inter-American Tropical Tuna Commission, 2019

The source species for byproduct fishmeal and fish oil are *Thunnus albacares and Katsuwomus pelamis* (see Table 11). As in Factor 5.1a, Seafood Watch partially considers the sustainability of the fisheries from which byproduct ingredients originate (at a rate of 5% of the inclusion level(s)), so as to recognize their ecological cost of production; please see the Seafood Watch Aquaculture Standard for additional details. According to FishSource, *Thunnus albacares* stock health is below its biological maximum sustainable yield (7), yet depending on the fishing method, Seafood Watch rates this fishery as Red, or Yellow. The *Katsuwonus pelamis* stock health is considered to be at or above the biological maximum sustainable yield by FishSource (≥8), although again, depending on the fishing method, Seafood Watch has rated the sustainability of the fishery as Red, or Yellow. To determine the Seafood Watch Source Fishery Sustainability Score for each species and fishing method, the Seafood Watch rating was used. A Red Seafood Watch rating for the fishery results in a score of 2, and a Yellow results in a score of 6.

In order to combine the Seafood Watch Source Fishery Sustainability Scores for *Katsuwonus pelamis* and *Thunnus albacares,* a weighted average was calculated by percentage of total catch and the seafood watch source fishery sustainability score between each species. This was done to obtain a proximate sustainability score that represents the likelihood of each fishing methods contribution to fish meal and fish oil. For each species fishing method, the resulting Seafood Watch Source Fishery Sustainability Score was multiplied by the percentage of total catch and summed for each species to determine the weighted average. The Percentage of total catch values were gathered from the Inter-American Tropical Tuna Commission (IATTC). According to IATTC, all of the *Katsuwonus pelamis* and *Thunnus albacares* caught in 2018 from Ecuador flagship vessels were from purse seines – though information about the particular purse seine type was not available. To determine this, it is assumed that the fraction of total catch from each purse seine type for all Easter Pacific Ocean is consistent with Ecuador's vessel landings. For Yellowfin Tuna this means 28% are caught with purse seines with FADs, 62% are caught with dolphin set purse seines, and 10% are caught with unassociated purse seines (non-FAD). For Skipjack tuna, 1% are caught with dolphin purse seines, 25% are caught with unassociated purse seines (non-FAD), and 74% are caught with purse seines with FADs.

The resulting weighted average score for Yellowfin, *Thunnus albacares,* is 6.88 and Skipjack, *Katsuwonus pelamis,* is 3.04. Combined, the average Seafood Watch Source Fishery Sustainability Score for these species is 4.96 (which is rounded to 5).

Considering the sustainability score of both wholefish and byproduct ingredients together (e.g. forage fish and yellowfin and skipjack fisheries), the final score for Factor 5.1b – Source fishery sustainability is 5.95.

When this score is combined with an FFER of 0.786 (Factor 5.1a), the final score for Factor 5.1 – Wild Fish Use is 7.00 out of 10.

Factor 5.2. Net Protein Gain or Loss

The crude protein content of the feed is 31.70%. The protein content is a weighted average representing 23 data points (20 from ASC reports, 2 from peer reviewed literature, and 1 from different diet formulas from Skretting).

With an eFCR of 1.55 (see Factor 5.1a for details), alongside a whole-shrimp protein content of 17.8% (Boyd et al., 2007), the net protein loss is -63.77%. This results in a score of 3 out of 10 for Factor 5.2 – Net protein gain or loss.

Table 12: The parameters used and their calculated values to determine the protein gain or loss in the production of farmed whiteleg shrimp from Ecuador.

Parameter	Data
Protein content of feed	31.70%
Economic Feed Conversion Ratio	1.55
Total protein INPUT per ton of farmed shrimp	491.35 kg
Protein content of whole harvested shrimp	17.8%
Total protein OUTPUT per ton of farmed shrimp	178.0 kg
Net protein loss	-63.77%
Seafood Watch Score (0-10)	**3**

Factor 5.3. Feed Footprint

Factor 5.3 – Feed Footprint is an approximation of the embedded global warming potential (kg CO_2-eq including land-use change (LUC)) of the feed ingredients required to grow one kilogram 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[6] to estimate the GWP of one metric ton of feed, followed by multiplying this value by the eFCR and the protein content of whole harvested seafood. Detailed calculation methodology can be found in Appendix 3 of the Seafood Watch Aquaculture Standard.

As noted previously, information about feed ingredients was gathered from one of the largest shrimp feed manufacturers in Ecuador (personal communication Skretting, 2020), personal communications, and primary literature. These sources were combined to develop a feed ingredient list and inclusion levels that are broadly reflective of a typical Ecuadorian shrimp feed.

Typical ingredients for Ecuadorian shrimp feed include fishmeal and fish oil (as explained in Factor 5.1), and terrestrial crop ingredients such as soybean products, wheat products, corn products, rice products, and yuca products (Tacon et al., 2011; personal communication Skretting, 2020; Molina-Poveda et al. 2014; Molina-Poveda et al. 2015). The degree to which inclusions of these ingredients vary depends on a number of different factors such as the manufacturing company, diet type, price of ingredient, and/or availability of the ingredient. Many of these ingredients are imported and while the origin of some ingredients are known (e.g. fishmeal and fish oil originate from Ecuador), it was not possible to make an approximation of origin for each ingredient, nor map each ingredient directly to the GFLI database, given the available data.

Fishmeal and fish oil ingredients (both whole fish and byproducts) of Ecuadorian origin are not found in the GFLI database, and the global (GLO) non-species-specific fishmeal and fish oil values (economic allocation) for global warming potential including land use change (GWP incl. LUC) values were used.

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

Soybean and wheat were both listed as key ingredients sourced from South America, but how much is sourced from each country or which countries was unavailable. It is assumed that "soybean" is soybean meal because of its common use as feed ingredients and listing by Tacon et al. (2011), while wheat product form is a grain (personal communication Skretting, 2020). Since the country of origin is not known for either ingredient, in both cases the average between the global (GLO) value and the worst listed value for soybean meal and wheat grain was applied following the methodology outlined in the Seafood Watch Aquaculture Standard.

Corn, yuca, and rice were listed as additional feed ingredients, but no further information (product form or origin) could be ascertained; as such, the total inclusion of these ingredients were aggregated and considered as "total vegetable meals (RER)" in the GFLI database.

Table 13: Estimated embedded global warming potential of one mt of a typical Ecuador shrimp feed.

Feed ingredients (≥2% inclusion)	GWP (incl. LUC) Value	Ingredient inclusion%	kg CO2 eq / mt feed
Fishmeal from wholefish	Fish meal, from fish meal and oil production, at plant/GLO Economic S	10.92%	101.67
Fishmeal from byproducts	Fish meal, from fish meal and oil production, at plant/GLO Economic S	9.7%	90.31
Terrestrial Crop Ingredients	Soybean meal, from crushing (solvent), at plant/GLO Economic S Soybean meal, from crushing (solvent), at plant/AR Economic S	73%	2088.03
	Wheat grain, production mix, at farm/PT Economic S Wheat grain, production mix, at farm/GLO Economic S		
	Total vegetable meals, at plant/RER Economic S		
	Sum of total	95.9%	**2290.40**

As can be seen in Table 13, the estimated embedded GWP of one mt of a typical Ecuador shrimp feed is 2,290.40 kg CO_2-eq. Considering a whole harvest shrimp protein content of 17.8% and an eFCR of 1.55, it is estimated that the feed-related GWP of one kg farmed shrimp protein is 20.95 kg CO_2-eq. This results in a score of 5 out of 10 for Factor 5.3 – Feed Footprint.

Conclusions and Final Score

In Ecuador, feed for whiteleg shrimp use fishmeal and fish oil that is made from whole wild fish and from byproduct sources. The fishmeal inclusion level is 20.62% and the fish oil inclusion level is 1.6%; with 47.05% of fishmeal and 31.25% of fish oil sourced from byproducts from the Ecuadorian tuna purse seine fishery, and the remaining 52.95% of fishmeal and 68.75% of fish oil originating from whole fish from the Ecuadorian forage fish purse seine fishery. The Forage Fish Efficiency Ratio (FFER) is low (0.786), meaning that 0.786 mt of wild fish are needed to produce the fishmeal required to produce one mt of farmed shrimp. The sustainability of the source fisheries is moderate and scores a 6 out of 10. Combined with a low FFER, the Factor 5.1 - Wild fish use score is a 7 out of 10. The net protein loss of -63.77% is high and results in score of 3 out of 10 for Factor 5.2 – Net protein gain or loss. The feed footprint is moderate with approximately 20.95 kg of CO_2-eq per kg of harvested protein, resulting in a score of 5 out of 10 for Factor 5.3 – Feed footprint. Altogether, the three factors combine to give a final score of 5.50 out of 10 for Criterion 5 -Feed.

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

Escape parameters	Value	Score
F6.1 System escape risk	4	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		4
F6.2 Competitive and genetic interactions		4
C6 Escape Final Score (0-10)		**4**
Critical?	NO	**YELLOW**

Brief Summary

The location, operation, and design of shrimp farms all contribute to the risk of shrimp escaping from farms and affecting wild populations. In Ecuador, farms are sited in areas that are prone to flooding, with 8% daily discharge rates into the surroundings watershed, but escape prevention methods like adequate height of perimeter farm dikes, use of screens at inlets and discharge points, and the use of netting during discharge help to reduce the risk of escapes. Therefore, there is a moderate risk of shrimp escaping from farms and Factor 6.1 is scored a 4 out of 10.

Whiteleg shrimp are native to the surrounding watersheds, but are assumed to be genetically distinct from wild populations and have phenotypic differences due to selective breeding practices. In the case of escaped farmed whiteleg shrimp, it is unlikely that any population level impacts would occur as a result of competitive or genetic interactions with wild whiteleg shrimp, and Factor 6.2 is scored a 4 out of 10.

Factors 6.1 and 6.2 combine to give a final numerical score of 4 out of 10 for Criterion 6 – Escapes.

Justification of Rating

L. vannamei is native to the Ecuadorian coast (FAO, 2006), and the escape of genetically distinct shrimp from farms can result in competitive and genetic interactions with wild populations. This criterion assesses the risk of escape and the competitive and genetic interactions of the escaping stock.

Factor 6.1. Escape risk

Characteristics driving the risk of farmed *L. vannamei* escaping from ponds include: location of farms, flooding events, pond construction and water circulation, frequency of pond discharge, and on-farm management practices.

Ecuadorian shrimp pond systems feature frequent water exchange at an average daily rate of 8% (personal communication CNA, 2020; personal communication Hiba, 2020). Ponds receive water from constructed inlet channels, where water is pumped from a neighboring waterbody (such as an estuary, seashore, or river) into the channel and then distributed to ponds. Daily discharge exits directly into drainage channels, which then return water directly into the waterbody (personal communication Hiba, 2020; personal communication Corsin, 2020; personal communication Piedrahita, 2020). Figure 8 shows a "typical Ecuadorian shrimp pond discharge system" (Hamilton, 2011), with a concrete and wooden dam that controls water height and discharge. During harvest, ponds are drained completely, directly into the drainage channels (Lucien-Brun, 2017; personal communication Higa, 2020) and farmers typically place netting over the discharge point to prevent shrimp from escaping (Hamilton, 2019; personal communication Hiba, 2020). There is no treatment of inflow or outflow water in Ecuadorian systems, and sedimentation ponds are not typically used (personal communication Hiba, 2020; personal communication Corsin, 2020; personal communication Piedrahita, 2020). Inlet and outlet screens are used with the appropriate mesh size matching shrimp size to help limit escapes (personal communication Piedrahita, 2020; personal communication Higa, 2020).

The risk of flooding events occurring and leading to escapes is moderate. The Guayas Basin is the largest "drainage basin of the South American western side of the Andes." (Frappart et al. 2017) and is where approximately 80% of shrimp production occurs in Ecuador (Piedrahita, 2018a). From December to May, the rainy season increases the risk of flooding events in this basin, but large scale flooding appears to occur during El Niño events when "socio-economic impacts on housing, agriculture and fisheries" have been documented (Frappart et al. 2017). For example, in 1997-1998 a very strong El Niño created an unprecedented flooding event that resulted in more than 450 deaths, and $3 billion in damages (Rosenberry, 1998). The shrimp industry was also impacted with an estimated 4,500 hectares of damaged shrimp ponds between Peru and Ecuador, which cost the industry nearly $60 million in damages (Rosenberry, 1998).

The impact and magnitude of the 1997-1998 El Niño event lingers to this day. More recent El Niño events have not been as strong, but the risk of flooding drives farmers to prepare for flooding and disruption. For example, farmers use sandbags to increase pond wall height and integrity, and, in some instances, potentially use boats instead of cars (due to the threat of floods and mudslides washing out roads) to transport shrimp harvests (Kase, 2016; Lozanova, 2015). In 2016, flooding of Guayaquil river initiated the Aquaculture subsector of the ministry of Agriculture to warn the 61,392 hectares of shrimp farms of possible large flooding events as the rain events began to flood cities, roads, and, ultimately impacted shrimp harvests, and production (Sackton, 2016; Mereghetti, 2017). The degree to which farms were impacted by this flooding event is not known, and the link between flooding and escape events are not mentioned.

To reduce the potential impacts of flooding, farms are constructed with earthen dikes that are designed to withstand storm surges, large tidal swings, and flooding events. In areas where tidal fluctuations and flooding risks are prevalent, dikes are constructed up to up to 3-5m in height (Hamilton, 2011; personal communication Hiba, 2020, personal communication Hamilton, 2020). In other areas where tidal fluctuations and flooding risks are reduced, such as the interior of the Chone estuary, pond dikes may be constructed about a foot or so above the pond water level (personal communication Hamilton, 2020).

Although flooding risks and impacts are apparent, there is no evidence of legislation, or industry led best practices beyond dike elevation and inlet and outlet screens that address the risk of escapes of *L. vannamei* from shrimp ponds to receiving waters. In general, farmers are not concerned about the impact of escapes to the surrounding watersheds because *L. vannamei* are native to the region (personal communication Hiba, 2020; personal communication Hamilton, 2020), and appear confident in the measures taken to prevent escapes from a financial perspective.

Figure 8: "A Typical Ecuadorian Shrimp Pond Discharge System. Picture was taken near the village of Salinas on the Northern side of Chone Estuary, January 2008." (Hamilton, 2011).

There are no studies in Ecuador that evaluate if escapes do or do not occur, but in other shrimp farming regions there is evidence of *L. vannamei* escapes in the literature. In Mexico, it was estimated roughly 7.1% of farmed *L. vannamei* shrimp escaped in 2012 and 2013 (Perez-Enriquez et al. 2018). In Thailand, evidence of farmed *L. vannamei* existing in the wild suggesting escape and the leading driver of escapes appears to be flooding events as farms are located in flood prone areas (Seekao and Pharino, 2016, 2016b; Senanan et al., 2007).

Overall, shrimp farms are located in areas that are susceptible to flooding events and there is a history of flooding, but this seems to coincide with El Niño events with the last significant event occurring in 1998. To mitigate against flooding events, farms typically build up dike walls, and in preparation to El Niño events will further add structural integrity in case of massive flooding. But, when flooding risk is not pressing, the issue of escapes does not appear to be a significant farm management concern. There are no prevention measures in place to limit escapes other than using screens at inlet and outlets and using nets over discharge points at harvest. There is no primary literature investigating escapes from farms into the wild in Ecuador, but recent studies of Mexico and Thailand *L. vannamei* pond farming demonstrate that this can occur. As a result, the escape risk is considered moderate, representative of ponds with moderate average annual daily exchange (8%) and drain externally at harvest; the score for Factor 6.1 – Escape Risk is 4 out of 10.

Factor 6.2. Competitive and genetic interactions

Whiteleg shrimp are native to the Ecuadorian Pacific coast where they are farmed. As such, in the event of an escape, there is concern for competition, the spread of disease and possible genetic introgression into wild populations (Wakida-Kusunoki *et al.*, 2011; Perez-Enriquez *et al.*, 2018).

In the 1970s, the Ecuadorian industry relied on wild *L. vannamei* as the source for post larvae, but by 1990 the industry had evolved, investing in the development of roughly 200 hatcheries throughout Ecuador (Stern and Sonnenholzner, 2011). Broodstock facilities began rearing *L. vannamei* helping to shift production reliance from wild *L. vannamei* to a closed production cycle in the 1990s. By the turn of the century, it was illegal to harvest wild *L. vannamei* for aquaculture purposes (Stern and Sonnenholzner, 2011, Acuerdo 106 Prohibicion de captura larva silvestre 2002).

Now, hatchery broodstocks have been raised for multiple generations and selectively bred for traits that include increased growth rates, and improved disease resistance (Seafood TIP, 2019; Moss et al. 2005). As a result, farmed shrimp are considered to be genetically distinct from wild conspecifics.

There is no primary literature that could be found that identifies what, if any, ecological and/or genetic introgression risk may be occurring from escaped *L. vannamei* to the wild *L. vannamei* populations in Ecuador; however, some insight was able to obtained from studies along the Central American Pacific coast from Mexico to Panama. Although these studies on the species' genetic diversity are able to identify subpopulations along the Pacific coast under study, they note that while genetic diversity is high in any one location, there was a lack of a specific geographical pattern and a low differentiation (i.e. genetic homogeneity) among estuaries (Valles-Jimenez *et al.*, 2004; Perez-Enriquez *et al.*, 2018). Therefore, given the high genetic diversity in the wild population as a whole plus the lack of highly discreet subpopulations (e.g. compared to salmon in which genetic introgression from escapes into highly discreet genetic subpopulations is a high concern, Glover et al., 2017), the potential for genetic introgression of farm shrimp escapes seems presently limited along the Central American coast. A study by Garcia and Alcivar-Warren (2007) indicated similar levels of genetic diversity amongst Ecuadorian stocks of wild *L. vannamei* as compared to Mexican, though caution must be exercised given small sample sizes; however, in the absence of additional information, it is assumed that Ecuadorian populations of *L. vannamei*, like Central American stocks studied, exhibit high genetic diversity and lack highly discreet subpopulations.

There is also no evidence that wild population stocks are being depleted due to escaped farmed *L. vannamei* and subsequent competition. There is no Fish Source or Seafood Watch assessment of Ecuador wild *L. vannamei* fisheries that may reflect any potential impacts or stock performance issues.

Given that farmed *L. vannamei* in Ecuador have been bred for multiple generations with clear evidence of selected characteristics, they are genetically distinct from native wild *L. vannamei* populations. If farmed *L. vannamei* escape, there is no evidence that demonstrates a genetic, or ecological impact to wild *L. vannamei* is occurring, however. Further, any competitive or genetic impacts that may occur due to escaped shrimp are not considered likely to affect the population status of wild *L. vannamei* due to significant genetic diversity amongst wild populations. As a result, the concern for competitive and genetic interactions is moderate and the score for Factor 6.2 is 4 out of 10.

Conclusions and Final Score

The location, operation, and design of shrimp farms all contribute to the risk of shrimp escaping from farms and affecting wild populations. In Ecuador, farms are sited in areas that are prone to flooding, with 8% daily discharge rates into the surroundings watershed, but escape prevention methods like adequate height of perimeter farm dikes, use of screens at inlets and discharge points, and the use of netting during discharge help to reduce the risk of escapes. Therefore, there is a moderate risk of shrimp escaping from farms and Factor 6.1 is scored a 4 out of 10.

Whiteleg shrimp are native to the surrounding watersheds, but are assumed to be genetically distinct from wild populations and have phenotypic differences due to selective breeding practices. In the case of escaped farmed whiteleg shrimp, it is unlikely that any population level impacts would occur as a result of competitive or genetic interactions with wild whiteleg shrimp, and Factor 6.2 is scored a 4 out of 10.

Factors 6.1 and 6.2 combine to give a final numerical score of 4 out of 10 for Criterion 6 – Escapes.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Risk-Based Assessment

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	4	
Critical?	NO	**YELLOW**

Brief Summary

As disease data quality and availability regarding the disease impact on the ecosystem is moderate/low (i.e. Criterion 1 scored 5 out of 10 for the disease category), the Seafood Watch Risk-Based Assessment method was utilized. The historical outbreaks of disease on shrimp farms in Ecuador are well documented, and the industry has demonstrated resilience while adopting practices and techniques to help mitigate against the risk of outbreaks. Mitigation measures include exclusion practices (biosecurity), improved genetic resilience of broodstock programs, farm management practices to improve environmental conditions, and governance structures that help to organize traceability systems, regulations and cooperation within the industry and with other international organizations. These strategies have proven effective at limiting viral disease occurrence on farms despite the openness of the production system. From 2011-2019, there have been zero positive cases for YHV, IMNV, TSV, NHPB, or AHPND/EMS, though WSSV and IHHNV continue to occur, albeit at low prevalence (never exceeding 7%). The biggest disease threat for Ecuadorian farmers is vibriosis. Although *Vibrio spp.* are ubiquitous in aquatic environments, prevalence of clinical disease at any given time is estimated at 20% across the industry. The direct mortality rate vibriosis has upon the industry is unclear, but the mortality rate for the industry overall is 50-90% (personal communication CNA, 2020; HATCH, 2019). It is therefore likely, given low positivity rates of viral diseases, that vibriosis is quite impactful to the industry and commonly results in on-farm mortalities despite the lack of clinical outbreaks. However, *Vibrio* spp. commonly cause mortality amongst wild juvenile shrimp as well, and the low-density production strategy employed by Ecuadorian shrimp farmers suggests that on-farm mortalities do not increase the likelihood of pathogen amplification compared to natural populations. Thus, the impact of disease, mainly vibriosis, is considered to occasionally reduce survival or increases the mortalities on farms and the production system discharges water on multiple occasions during the production cycle without relevant treatment. As such, the risk of disease is considered moderate and results in a final score of 4 out of 10 for Criterion 7 – Disease.

Justification of Rating

Risk-based assessment:

As disease data quality and availability is moderate/low (i.e. Criterion 1 score of 5 or lower for the disease category), the Seafood Watch Risk-Based Assessment was utilized.

Globally, the shrimp farming industry has been subjected to a series of bacterial and viral outbreaks beginning in the early 1980s, which have caused major economic impacts to the sector. The sources of these outbreaks can vary; for example, disease outbreaks can originate from feed, culture conditions, and international trade of products (Nunan et al. 1998; Durand et al. 2000; McColl et al 2004; Hasson et al. 2006). Major pathogens of concern for farmed *L. vannamei* include white spot syndrome virus (WSSV), yellow head virus (YHV), Taura syndrome virus (TSV), infectious myonecrosis virus (IMNV), necrotizing hepatopancreatitis (NHP), infectious hypoderma and haematopoietic necrosis virus (IHHNV), and early mortality syndrome (EMS) or Acute hepatopancreatic necrosis disease (AHPND) (World Organization for Animal Health (OIE) 2020).

In Ecuador, three viruses have impacted *L. vannamei* farms over time: Infectious hypodermal and haemeatopoietic necrosis virus (IHHNV), Taura Syndrome Virus (TSV), and White Spot Syndrome Virus (WSSV) (see Figure 9).

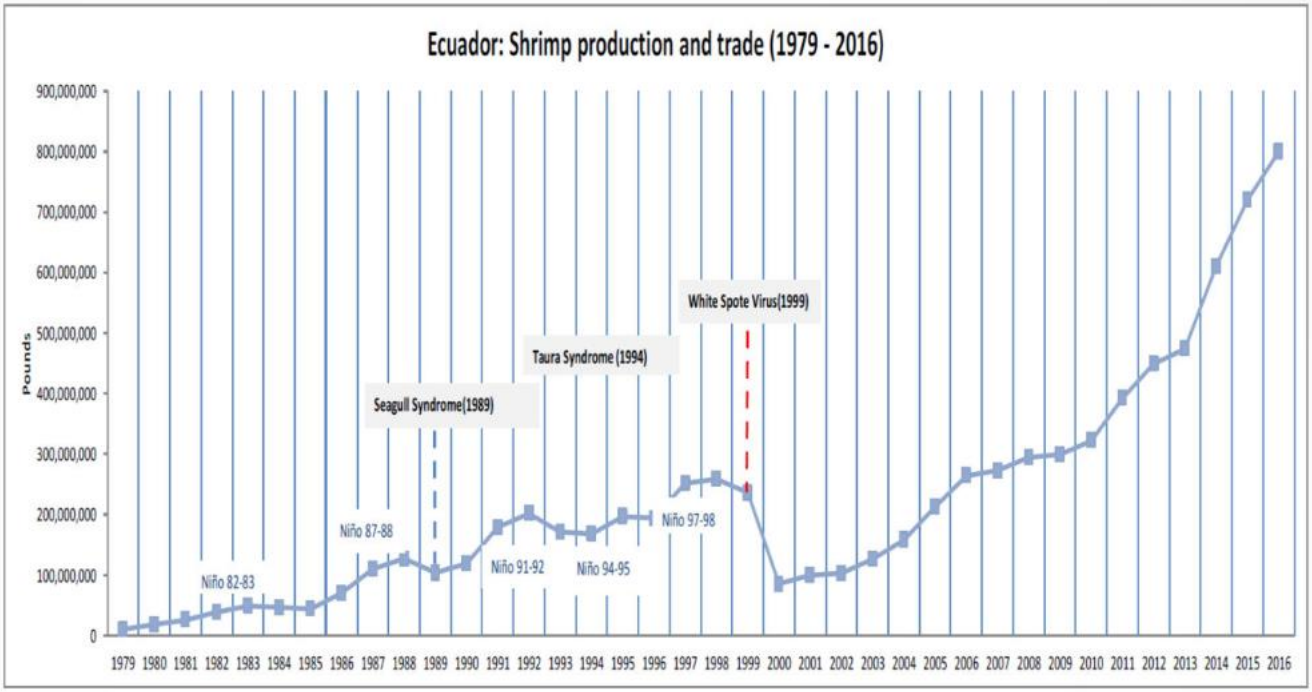

Figure 9: Ecuador Whiteleg Shrimp Farming Production from 1979 to 2016. Graph illustrates years when IHHNV (1987), TSV (1993), and WSSV (2000) impacted production totals. Source: Piedrahita, 2018a

Infectious hypodermal and haemeatopoietic necrosis virus (IHHNV) hit Ecuador in 1987. It is a viral disease, but does not necessarily cause significant mortalities, (Lightner, 2011) yet can cause runt deformity syndrome (RDS) which slows growth and can create economic losses of 10-50% per crop (Walker and Mohan, 2009). IHHNV is a “small (22nm) non-enveloped DNA virus with icosahedral symmetry” (Walker and Mohan, 2009) and can be transmitted horizontally (between animals of the same species) and vertically (from broodstock to offspring) (Walker and Mohan, 2009).

Taura Syndrome Virus was discovered in shrimp ponds near the Taura River of Ecuador in 1992 (Walker and Mohan, 2009). It spread rapidly to other parts of the world likely due to the international trade of postlarvae and broodstocks and the mortalities can range from 40 to greater than 90% in postlarval populations (Walker and Mohan, 2009; Lightner 2011). Horizontal, vertical, and mechanical transmission routes have all been cited in the literature (Walker and Mohan, 2009).

White Spot Syndrome Virus (WSSV) was found in Ecuador in 2000 and quickly became an epidemic (Walker and Mohan, 2009; Restrepo et al. 2018). WSSV is a “large, ovaloid, DNA virus with a lipid envelope that features an unusual tail-like appendage.” (Walker and Mohan, 2009). WSSV has an 80 to 100% mortality rate within just 5 to 10 days of the first clinical signs (Chou et al. 1995). Triggers for WSSV outbreaks include physiological stress, salinity change and lower water temperatures (Walker and Mohan, 2009).

There have been no documented mass disease outbreaks in Ecuador since the initial WSSV outbreak in 2000, which caused production to contract by 70% (Piedrahita, 2018a). Production totals have increased nearly every year since the WSSV outbreak (see Figure 9), but more recent issues may signal disease outbreak occurrences. On September 10th 2019, China blocked imports from three processing plants: Santa Priscila, Omarsa, and Winrep (Navarro, 2019). The Santa Priscila shipment was reportedly blocked due to detection of WSSV, and an Omarsa shipment was blocked due to detection of yellowhead virus (YHV) (Navarro, 2019). After a meeting between Ecuadorian and Chinese officials one week later, the block of Omarsa shipments was lifted after an analysis of the shipment "ruled out the presence of yellow head" (Lozano, 2019). Ecuador has never had any issues with YHV in the past (Lozano, 2019). The blockade on Santa Priscila and Winrep was lifted after November 27th, 2019 (N. Unlay, D. Korbin, 2019).

The Undersecretariat of Quality and Safety administers and executes the National Control Plan, which "certify[ies] the quality of the exported shrimp and to ensure traceability throughout the entire commercial chain." Although the National Control Plan (NCP) mostly focuses on the processing side of the value chain, it creates an organized traceability system to help identify if/where disease may be occurring. As part of the NCP, testing for shrimp disease is performed by a certified national laboratory. According to the Undersecretariat of Quality and Safety (2019), the percentage of samples that tested positive for WSSV, IHHNV, YHV, infectious myonecrosis virus (IMNV), TSV, Necrotizing hepatopancreatitis bacteria (NHPB), and Acute hepatopancreatic necrosis disease (AHPND)/ Early Mortality Syndrome (EMS) are shown from 2011 to 2019 in the Table 14. Results demonstrate the low occurrence of positive cases for all diseases, although it is unclear what part of the production chain these samples were taken from. For this insight, data for the year 2019 was obtained, which shows the number of samples that tested positive for IHHNV and WSSV for each production node; all were below 8% (see Table 15 and 16). Combined, this data suggests that concern for disease outbreaks is low on farms, but IHHNV (5.97%) tested at a higher percentage than WSSV (2.63%) on sampled farms. in 2019.

Table 14: The percentage of samples that tested positive for WSSV, IHHNV, YHV, infectious myonecrosis virus (IMNV), TSV, Necrotizing hepatopancreatitis bacteria (NHPB), and Acute hepatopancreatic necrosis disease (AHPND)/ Early Mortality Syndrome (EMS) from 2011 to 2019. Source: SCI, 2019

Year	Number of Samples	WSSV+	IHHNV+	YHV+	IMNV+	TSV+	NHPV	AHPND/EMS
2011	4014	1%	0%	0%	0%	0%	0%	*NA*
2012	4104	0%	1%	0%	0%	0%	0%	*NA*
2013	6927	6%	7%	0%	0%	0%	0%	0%
2014	7915	7%	5%	0%	0%	0%	0%	0%
2015	9693	5%	3%	0%	0%	0%	0%	0%
2016	9114	3%	1%	0%	0%	0%	0%	0%
2017	10147	3%	4%	0%	0%	0%	0%	0%
2018	22919	3%	6%	0%	0%	0%	0%	0%
2019	13362	2%	6%	0%	0%	0%	0%	0%

Table 15: Number and percentage of positive WSSV samples in 2019 from each component of the production chain. Source: SCI, 2019

Production Chain	Number of Samples	WSSV+	Prevalence %
Broodstock	710	3	0.50%
Hatchery	984	0	0.00%
Shrimp Farms	3360	87	2.63%
Processing Center	1859	100	5.30%

Table 16: Number and percentage of positive IHHNV samples in 2019 from each component of the production chain. Source: SCI, 2019

Production Chain	Number of Samples	IHHNV+	Prevalence %
Broodstock	1140	11	0.96%
Hatchery	4560	23	0.50%
Shrimp Farms	7884	471	5.97%
Processing Center	3477	244	7.02%

Currently, bacterial diseases, specifically, vibriosis, cause the most concern for Ecuador shrimp farmers (personal communication CNA, 2020). *Vibrio* species from the family Vibrionacea are ubiquitous throughout the world. Rapid growth of *Vibrio spp.* in shrimp ponds and/or physiological and environmental stress to farmed *L. vannamei* can lead to vibriosis, a significant disease that can impact *L. vannamei* production and cause significant mortality (Raja et al. 2017). Symptoms of vibriosis include lethargy, anorexia, hemorrhages, discoloration, necrosis of the exoskeleton, ulcers and can also impact internal organs (Raja et al. 2017). In Ecuador, the maximum prevalence of vibriosis is around 20% for the industry with the most frequent issues occurring in the rainy season when temperatures are the highest from December to February (personal communication CNA, 2020). To manage vibriosis, pond water is treated with lime or calcium hydroxide prior to stocking, and therapeutics such as organic acids and probiotics are added to the water during culture to improve shrimp health (personal communication CNA, 2020). It's also estimated that a minority of farms (<10%) use antibiotics as a treatment for vibriosis (personal communication CNA, 2020).

Documentation of the positivity rate for vibriosis was not found, but it has been reported that the prevalence of vibriosis is around 20%. The direct mortality rate vibriosis has upon the industry is unclear, but the mortality rate for the industry overall is 50-90% (personal communication CNA, 2020; HATCH, 2019). It is therefore likely, given low positivity rates of viral diseases, that vibriosis is quite impactful to the industry and commonly results in on-farm mortalities despite the lack of clinical outbreaks.

To limit potential disease outbreaks and the subsequent economic repercussions, mitigation measures have been adopted across Ecuadorian shrimp farms. Since the expression of disease in aquaculture is due to the interaction of the cultured species, the environment, and pathogens as described by Snieszko (1974) it is important that "any effective disease-control program use a multifactorial approach…" as there is "no single magic bullet that can solve any or every disease problem." (Flegel, 2019). The multifactorial mitigation approach in Ecuador includes on-farm biosecurity, breeding for improved genetics and disease resistance, low density culture methodology, and restricting imports of live animals.

Biosecurity measures primarily focus on pathogen exclusion from visitors to farms. Recommended measures include training and education of staff on the importance of biosecurity, documentation of anything that enters and leaves the farm, disinfection of people and cars entering the farm, informing all guests of biosecurity rules, and requiring/providing safety clothing upon entry (recommended to be disposable) (Organic Environment Code, 2018). In the case of a perceived disease outbreak, actions are taken immediately. If mortality higher than 80% occurs over the course of 48 hours, then all shrimp must be harvested, and incinerated (Rosenberry, 2018). Also, to limit the risk of foreign shrimp disease introductions, Ecuador does not allow for the importation of any live shrimp (Piedrahita, 2018b; Welling, 2019).

In addition, Ecuador relies on a hatchery production model called "pathogen tolerant breeding" or specific pathogen resistant (SPR), which supplies grow out farms with post larvae (PL) that have been selected for high survival and resistance or tolerance to WSSV, TSV, and EMS (Lucien-Brun, 2017; Seafood TIP, 2018; Wyban, 2019). Since farm water input is not tightly controlled and farm production systems are open to the environment through frequent water exchange, selecting for PLs that are resistant to known pathogens in the farming environment helps to create a more resilient disease mitigation strategy (personal communication Piedrahita, 2020).

Farm management practices that are implemented to promote healthy growing environment and to minimize disease outbreaks include maintaining low stocking densities, implementing automatic feeding technologies that reduce feed waste, installing aeration into some ponds, and the use of probiotics and organic acids (CEA, 2018; Seafood TIP, 2018 and Lucien-Brun, 2017; Wyban, 2019; personal communication Higa, 2020; personal communication CNA, 2020).

Ecuadorian shrimp farmers have initiated a national industry association, Camara Nacional de Acuacultura (CNA), to help provide governance for the industry to minimize disease issues. In 2013, Ecuador avoided outbreaks of EMS by leveraging its organizational structure, CNA, to work with experts and national authorities to implement a sanitary barrier that "prohibited the importation of shrimp in any of its development phases and products, and restricted the entry of certain inputs from countries where the disease had been declared or where there were atypical mortalities." (Piedrahita, 2018b). This barrier helped to reduce disease risk of AHPND, and Ecuador has largely remained unaffected by this disease.

Despite high total mortality of juvenile shrimp in Ecuadorian shrimp ponds, the industry has effectively managed disease risk such that clinical bacterial disease (Vibriosis) is limited to <20% of farms at any given time, and viral pathogens limited to <7% prevalence. Given how ubiquitous *Vibrio* species are in the environment, the openness of Ecuador production systems, combined with the strategic decision to use pathogen resistant post larva, it is apparent that the Ecuadorian industry has implemented a strategy of balancing disease risks with limited farming intensity and stress reduction. Stocking densities are low, daily water exchange rate is high, and the application of organic acids and probiotics is common. This approach has largely succeeded, as there have been no documented significant disease outbreaks over the past 20 years. Results from the SCI indicate that from 2011-2019, there have been zero positive cases for YHV, IMNV, TSV, NHPB, or AHPND/EMS, but positive results for WSSV and IHHNV have occurred though the rate has never been above 7% (it is unclear at what point in the production chain these results represent). In a separate dataset, data for positivity rates of IHHNV and WSSV on farms is available for 2019, and IHHNV (5.97%) tested at a higher percentage than WSSV (2.63%).

Overall, it is therefore likely, given low positivity rates of viral diseases, that vibriosis is quite impactful to the industry and commonly results in on-farm mortalities despite the lack of clinical outbreaks. However, *Vibrio* spp. commonly cause mortality amongst wild juvenile shrimp as well, and the low-density production strategy employed by Ecuadorian shrimp farmers suggests that on-farm mortalities do not increase the likelihood of pathogen amplification compared to natural populations. Thus, the impact of disease, mainly vibriosis, is considered to occasionally reduce survival or increases the mortalities on farms and the production system discharges water on multiple occasions during the production cycle without relevant treatment. As such, the risk of disease is considered moderate and results in a final score of 4 out of 10 for Criterion 7 – Disease.

Conclusions and Final Score

As disease data quality and availability regarding the disease impact on the ecosystem is moderate/low (i.e. Criterion 1 scored 5 out of 10 for the disease category), the Seafood Watch Risk-Based Assessment method was utilized. The historical outbreaks of disease on shrimp farms in Ecuador are well documented, and the industry has demonstrated resilience while adopting practices and techniques to help mitigate against the risk of outbreaks. Mitigation measures include exclusion practices (biosecurity), improved genetic resilience of broodstock programs, farm management practices to improve environmental conditions, and governance structures that help to organize traceability systems, regulations and cooperation within the industry and with other international organizations. These strategies have proven effective at limiting viral disease occurrence on farms despite the openness of the production system. From 2011-2019, there have been zero positive cases for YHV, IMNV, TSV, NHPB, or AHPND/EMS, though WSSV and IHHNV continue to occur, albeit at low prevalence (never exceeding 7%). The biggest disease threat for Ecuadorian farmers is vibriosis. Although *Vibrio spp.* are ubiquitous in aquatic environments, prevalence of clinical disease at any given time is estimated at 20% across the industry. The direct mortality rate vibriosis has upon the industry is unclear, but the mortality rate for the industry overall is 50-90% (personal communication CNA, 2020; HATCH, 2019). It is therefore likely, given low positivity rates of viral diseases, that vibriosis is quite impactful to the industry and commonly results in on-farm mortalities despite the lack of clinical outbreaks. However, *Vibrio* spp. commonly cause mortality amongst wild juvenile shrimp as well, and the low-density production strategy employed by Ecuadorian shrimp farmers suggests that on-farm mortalities do not increase the likelihood of pathogen amplification compared to natural populations. Thus, the impact of disease, mainly vibriosis, is considered to occasionally reduce survival or increases the mortalities on farms and the production system discharges water on multiple occasions during the production cycle without relevant treatment. As such, the risk of disease is considered moderate and results in a final score of 4 out of 10 for Criterion 7 – Disease.

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

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

Brief Summary

Based on available data, all Ecuadorian broodstock are hatchery-raised and there is no dependence on wild populations; subsequently, there are no impacts relating to the source of stock. The numerical score for Criterion 8 – Source of Stock is 0 out of -10.

Justification of Rating

In the 1970s, the Ecuadorian industry relied on wild *L. vannamei* as the source for post larvae, but by 1990 the industry had evolved, investing in the development of roughly 200 hatcheries throughout Ecuador (Stern and Sonnenholzner, 2011). Broodstock facilities began rearing *L. vannamei* helping to shift production reliance from wild *L. vannamei* to a closed production cycle in the 1990s. By the turn of the century, it was illegal to harvest wild *L. vannamei* for aquaculture purposes (Stern and Sonnenholzner, 2011, Acuerdo 106 Prohibicion de captura larva silvestre 2002). After the outbreaks of TSV and WSSV in the 1990s, Ecuador used broodstock selection practices to enhance disease resistance in farm stocks (Moss et al. 2005). All deliberately stocked PLs used in the industry are hatchery-raised and broodstock are selected from farms (Stern and Sonnenholzner, 2011). As such, there is no dependence on wild populations for the source of stock and the numerical score for Criterion 8X – Source of stock is 0 out of -10.

Conclusions and Final Score

Because 0% of farmed stock is dependent on wild broodstock/wild post-larvae, the final numerical score for Criterion 8X – Source of stock is 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

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0-10)	**-2**	
Critical?	NO	**GREEN**

Brief Summary

The data regarding the impact that predator control at shrimp farms has on wild species is poor, and the Risk-Based Assessment method was used. Overall, it is understood that Ecuadorian shrimp farms may interact with predators and other wildlife, and farmers primarily utilize nonlethal control methods to limit interactions; thus, it is considered that management practices for non-harmful exclusion are in place. However, there is limited information available to determine whether any mortality (accidental or intentional) is occurring. According to the Organic Code of Environment (2018) it is forbidden to take animals from the wild, unless for hunting purposes for consumption – and there does not appear to be exceptions for shrimp farming. It is unclear whether a permit is needed for take, or whether a permit process is available for shrimp farmers to take animals that are interacting with their farm. There are also protections for endangered species under Ecuadorian law consistent with international treaties of migratory species. Of the known species that interact with aquaculture farms, the majority have a population level of least concern, but 2 species are listed as near threatened, 5 mammal species are listed as threatened and 4 mammal species and 1 bird species are listed as vulnerable. However, there is no documentation that aquaculture operations are using lethal control towards these species or that suggest or claim aquaculture is the reason for the conservation status of these species.

It appears that deliberate lethal wildlife control is not permitted, and accidental mortalities are likely to be limited to exceptional cases or are considered highly unlikely to affect the health of the population. Therefore, the score for Criterion 9x – Wildlife Mortalities is -2 out of -10.

Justification of Rating

The confidence in the data regarding the impact that predator control at shrimp farms has on wild species is poor, and the corresponding Criterion 1 – Data score is 2.5 out of 10. As such, the Risk-Based Assessment method was used.

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). In general, predators on shrimp farms that can feed directly on shrimp can include amphibians, birds, crustaceans, finfish, mammals, and snakes (FAO 1986).

Ecuador has converted 93% of its salt marsh habitat, and roughly 55,920 hectares of mangrove forests across Ecuador from 1970 to 2014 (Hamilton, 2019). In the case of mangrove forests, the predominant land use change from mangroves forests was to shrimp farming (Hamilton, 2019). Bietl (2016) estimate that roughly 20,000 hectares of salt flats have been converted to shrimp farming production, nationally, with the rate of decline the greatest from 1984 to 1991. The animals dependent on these once coastal wetlands seek substitutable habitat types. Human-modified habitats like shrimp ponds are known to be a frequent substitute for species seeking a wetland like environment (Cheek, M. D., 2009). However, wildlife interactions on aquaculture sites can have negative economic and health impacts on farmed species. To minimize these interactions and associated risks, aquaculture operations may implement control and management measures.

In Ecuador, non-lethal control methods are typically employed, while evidence of lethal control is limited. Prior to stocking shrimp for grow out, herbicides and pesticides like fluoride, organic acids, calcium carbonate and lime are applied to ponds to remove unwanted vegetation and non-shrimp fauna (Hamilton, 2019). Non-lethal frightening techniques used on farms to scare away wildlife can include setting off fireworks or releasing barking dogs (ASC, 2018). There are no reported lethal practices (other than potential pesticide use) and it is uncertain whether or not lethal control is permitted. There have been observations of cormorants dead due to apparent gunshot wounds near farms (Cheek, M.D., 2009). However, this is a single observation, from over ten years ago and IUCN lists this species of cormorants as “least concern” with an increasing population trend (IUCN, 2018). Therefore, lethal techniques are considered to be limited and is highly unlikely to affect the health of the population.

The non-lethal control methods described are used for different types of wildlife species like birds, mammals, and reptiles that have habitat ranges overlapping with shrimp aquaculture ponds. Mammal species such as bats, monkeys, small cats and mice have been spotted at farms in Ecuador (see Table 17), and the International Union for Conservation of Nature (IUCN) list some of these species as vulnerable, and near threatened (ASC, 2019, Personal communication Santa Priscila S.A., 2019; IUCN, 2019). Many different types of bird species frequent aquaculture ponds in Ecuador as well (see Table 17)(Cheek, 2009; ASC, 2018; ASC, 2019; Personal communication Santa Priscila S.A., 2019).

Table 17: Mammal, reptile, and bird species spotted at farms in Ecuador and their IUCN conservation status. (ASC, 2018, ASC, 2019; Cheek, 2009; Personal communication Santa Priscila S.A., 2019; IUCN, 2019).

Common Name	*Genus species*	IUCN Status
Ecuadorian Howling Monkey	*Alouata palliata aequatorialis*	Least Concern
Neotropical otter	*Lontra longicaudis*	Near Threatened
Bat	*Aertibeus aequatorialis*	Least Concern
White-faced capuchin	*Cebus capucinus*	Vulnerable
Long-tailed bat	*Choeroniscus periosus*	Vulnerable
Narrow footed bristly mouse	*Neacomys tenuipes*	Vulnerable
Red Brocket	*Mazama amaericana*	Data Deficient
Northern tiger cat	*Leopardus tigrinus*	Vulnerable
Vampire bat	*Desmodus rotundus*	Least Concern
Talmancan Rice Rat	*Oryzomys talamancae*	Least concern
Common Opossum	*Didelphis marsupialis*	Least concern
Chipmunk	*Sciurus stramineus*	Least Concern
Whorltail iguana	*Stenocercus iridescens*	Least Concern
Veronica's Anole	*Anolis festae*	Least Concern
Speckled Worm Lizard	*Amphisbaena fuliginosa*	Least Concern
Tricolored heron	*Egretta tricolor*	Least Concern
Little blue heron	*Egretta caerulea*	Least Concern
Yellow crowned night heron	*Nyctanassa violacea*	Least Concern
Striated heron	*Butorides striatus*	Unknown
Neotropical cormorant	*Phalacrocorax brasilianus*	Least Concern
Great white egrets	*Aredea alba*	Least Concern
Black necked stilt	*Himantopus mexicanus*	Unknown
Brown wood-rail	*Aramides wolfi*	Vulnerable
Elegant tern	*Thalasseus elegans*	Near Threatened
Whimbrel	*Numenius phaepous*	Least Concern
Purple gallinule	*Porphyrio martinicus*	Least Concern
Green backed heron	*Butorides striata*	Least Concern
White ibis	*Eudocimus albus*	Least Concern
Grey heron	*Ardea cinerea*	Least Concern
Cocoi heron	*Ardea cocoi*	Least Concern
Osprey	*Pandion haliaetus*	Least Concern
Green kingfisher	*Chloroceryle Americana*	Least Concern
Roseate spoonbill	*Platalea ajaja*	Least Concern
Magnificent frigatebird	*Fregata magnificens*	Least Concern

Of the reported species seen on farms, 2 species are listed as near threatened, 5 mammal species are listed as threatened and 4 mammal species and 1 bird species are listed as vulnerable (according to the IUCN). Three of these species, the neotropical otter, brown wood-rail and the northern tiger cat populations have decreasing trends, but the drivers listed by IUCN do not include aquaculture.

In 2008, Ecuador amended its constitution to include the Rights of Nature “where indigenous values and ideals emphasize the intrinsic interconnection of human, ecological, and cosmological realms of existence.” (Bietl, 2016). Given the clear values set forth by the Rights of Nature, the idea of harm, or take of wildlife that may be interacting with shrimp ponds may be counter to national and individual perspectives. According to Piedrahita (personal communication, 2020) farmers view wildlife interactions as natural occurrences.

Protections for animals are detailed in the Organic Code of Environment (2018). This legislation creates protections for animal welfare and states it is forbidden to “Cause death to animals, except those destined for consumption and those that represent transmission risk of diseases.” (Organic Code of Environment, 2018). Endangered species, as designated by international treaties or by the Ministry of Environment, are protected from take, and failure to comply can lead up to 3 years of imprisonment (Organic Environment Code, 2018).

Overall, Ecuador shrimp farms impacts to wildlife is low. Wildlife management practices on Ecuadorian shrimp farms use non-lethal methods to control wildlife and farm interactions. There is limited evidence of lethal control methods used on shrimp farms. One account found reported gunshot-related mortalities of neotropical cormorants on farms, however this observation was made over ten years ago, and the species is listed as ‘least concern’ with an increasing population trend according to IUCN.

Conclusions and Final Score

The data regarding the impact that predator control at shrimp farms has on wild species is poor, and the Risk-Based Assessment method was used. Overall, it is understood that Ecuadorian shrimp farms may interact with predators and other wildlife, and farmers primarily utilize nonlethal control methods to limit interactions; thus, it is considered that management practices for non-harmful exclusion are in place. However, there is limited information available to determine whether any mortality (accidental or intentional). According to the Organic Code of Environment (2018) it is forbidden to take animals from the wild, unless for hunting purposes for consumption – and there does not appear to be exceptions for shrimp farming. It is unclear whether a permit is needed for take, or whether a permit process is available for shrimp farmers to take animals that are interacting with their farm. There are also protections for endangered species under Ecuadorian law consistent with international treaties of migratory species. Of the known species that interact with aquaculture farms, the majority have a population level of least concern, but 2 species are listed as near threatened, 5 mammal species are listed as threatened and 4 mammal species and 1 bird species are listed as vulnerable. However, there is no documentation that aquaculture operations are using lethal control towards these species or that suggest or claim aquaculture is the reason for the conservation status of these species.

It appears that deliberate lethal wildlife control is not permitted, and accidental mortalities are likely to be limited to exceptional cases or are considered highly unlikely to affect the health of the population. Therefore, the score for Criterion 9x – Wildlife Mortalities is -2 out of -10.

Criterion 10X: Escape 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

Escape of secondary species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10	
F10Xb Biosecurity of source/destination		
C10X Escape of secondary species Final Score	**0.00**	**GREEN**

Brief Summary

Ecuador has broodstock and hatchery production infrastructure that supplies all of the farms demand for *L. vannamei* and Ecuador does not allow the importation of live shrimp. The movement of post larvae from hatchery to grow out farms is not considered to be trans-waterbody.

The final numerical score for Criterion 10X – Escape of Unintentionally Introduced Species is 0 out of -10.

Justification of Rating

Factor 10Xa International or trans-waterbody live animal shipments

Whiteleg shrimp farms in Ecuador only use hatchery-raised seed from domesticated broodstock. Broodstock populations are all maintained in maturation facilities within Ecuador and are periodically supplemented by individuals from growout ponds, as the importation of live shrimp is restricted (Piedrahita, 2018b; Welling, 2019; personal communication Piedrahita, 2020). There are roughly 20 broodstock facilities and 180 hatcheries, which are the sole providers for *L. vannamei* farming industry (Piedrahita, 2018a; Piedrahita, 2018b; Wyban, 2019). Broodstock and hatchery facilities are located throughout Ecuador's coastline, but are concentrated in the Guayas province where 60% of production occurs (personal communication Higa, 2020; Piedrahita, 2018).

The destination for postlarvae are growout farms, where 80% of production is in Guayas and El Oro provinces, 9% is located in Esmeraladas and Manabi provinces, and 2% in Santa Elena province. Shrimp farming in these provinces are located in estuaries. Ecuador has roughly 7 estuaries that have been developed by the shrimp farming industry: Muisne Estuary, Cojimies Estuary, Chone Estuary, Isla Puna North, Isla Puna, Guayas Estuary, and the estuaries of El Oro Province (Grande Estuary and many rivers to the north) (Hamilton, 2019). The estuaries of the El Oro and Guayas provinces, where 80% of production occurs, combine to the Gulf of Guayaquil – which is "the largest estuarine ecosystem on the Pacific coast of South America." (Twilley et al., 2001).

Although these estuaries are found in different watersheds, they appear to be ecologically similar and connected through oceanographic processes. Hamilton (2019) describes the biodiversity around the estuaries, but it did not appear that species were constrained or endemic to one estuary or another, but the same species could be found in multiple estuaries. The Ecuadorian coastline, and its estuaries are connected by the tides and overall flow of the Pacific Ocean. Upwelling events drive nutrient rich water to the surface (Fiedler, 1991), where 8 inter-connected currents distribute these nutrients to the north, east, and south (Collins, Mascarenhas, Martinez, 2013) connecting with estuaries along the way.

Overall, the Gulf of Guayaquil is one large estuary system, which represents 80% of production, and is also where the majority of hatchery and broodstock facilities are located, so there is minimal transwater body movement. Other movement, from one estuary to another, is likely to demonstrate low risk considering the connectedness of estuaries and the oceanographic characteristics that define the Ecuadorian coast. Therefore, the estuaries, and coastal system is considered to not be ecologically distinct waterbody but connected, and animal movement from one estuary to another does not represent a risk of introducing species that is not native or present in the destination waterbody.

Because 0% of production is reliant on international/trans-waterbody animal movements the score for Factor 10Xa is 10 out of 10.

Factor 10Xb Biosecurity of source/destination

Due to the reliance on seed that is produced within the same waterbody as the growout facilities, the cultivation of shrimp does not rely on international or trans-waterbody movements and Factor 10Xb is not applicable.

Conclusions and Final Score

Ecuador has broodstock and hatchery production infrastructure that supplies all of the farms demand for *L. vannamei* and Ecuador does not allow the importation of live shrimp. The movement of post larvae from hatchery to grow out farms is not considered to be trans-waterbody.

The final numerical score for Criterion 10X – Escape of Unintentionally Introduced Species is 0 out of -10.

Overall Recommendation

The overall recommendation is as follows:

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

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

Whiteleg shrimp

Litopenaeus vannamei

Ecuador

Semi intensive ponds

Criterion	Score	Rank	Critical?
C1 Data	5.23	Yellow	
C2 Effluent	5.00	Yellow	NO
C3 Habitat	3.47	Yellow	NO
C4 Chemicals	3.00	Red	NO
C5 Feed	5.45	Yellow	NO
C6 Escapes	4.00	Yellow	NO
C7 Disease	4.00	Yellow	NO
C8X Source	0.00	Green	NO
C9X Wildlife mortalities	-2.00	Green	NO
C10X Introduced species escape	0.00	Green	
Total	**28.144**		
Final score (0-10)	**4.021**		

OVERALL RANKING

Final Score	4.02
Initial rank	Yellow
Red criteria	1
Interim rank	Yellow
Critical Criteria?	NO

FINAL RANK
Yellow

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

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Appendix 1 - Data points and all scoring calculations

Criterion 1: Data	
Data Category	**Data Quality**
Production	7.5
Management	5.0
Effluent	5.0
Habitat	5.0
Chemical Use	2.5
Feed	5.0
Escapes	2.5
Disease	5.0
Source of stock	10.0
Wildlife mortalities	2.5
Escape of secondary species	7.5
C1 Data Final Score (0-10)	**5.227**
	Yellow

	Shrimp

Criterion 2: Effluent	
Effluent Evidence-Based Assessment	**Data and Scores**
C2 Effluent Final Score (0-10)	**6**
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 (%)	31.700
eFCR	1.550
Fertilizer N input (kg N/ton fish)	0.930
Protein content of harvested fish (%)	17.800
N content factor (fixed)	0.160
N input per ton of fish produced (kg)	79.546
N output in each ton of fish harvested (kg)	28.480
Waste N produced per ton of fish (kg)	51.066

2.1b Production System discharge	**Data and Scores**
Basic production system score	0.510

Adjustment 1 (if applicable)	0.000
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)	0.510
Waste discharged per ton of production (kg N ton-1)	26.044
Waste discharge score (0-10)	7.000

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	3
2.2 Effluent management effectiveness	3.600
C2 Effluent Final Score (0-10)	**5**
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	3
3.2 Habitat management effectiveness	2.400
C3 Habitat Final Score (0-10)	**3.467**
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 %	10.920
Fishmeal from byproducts, weighted inclusion %	9.700
Byproduct fishmeal inclusion (@ 5%)	0.485
Fishmeal yield value, weighted %	22.500
Fish oil from whole fish, weighted inclusion level %	1.100
Fish oil from byproducts, weighted inclusion %	0.500
Byproduct fish oil inclusion (@ 5%)	0.025
Fish oil yield value, weighted %	5.000
eFCR	1.550
FFER Fishmeal value	**0.786**
FFER Fish oil value	**0.349**
Critical (FFER >4)?	No

5.1b Sustainability of Source fisheries	**Data and Scores**
Source fishery sustainability score	5.950
Critical Source fisheries?	No
SFW "Red" Source fisheries?	Yes
FFER for red-rated fisheries	0.702
Critical (SFW Red and FFER >=1)?	No
Final Factor 5.1 Score	**6.900**

5.2 Net Protein Gain or Loss (%)	**Data and Scores**
Weighted total feed protein content	31.700
Protein INPUT kg/100kg harvest	49.135
Whole body harvested fish protein content	17.800
Net protein gain or loss	-63.773
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)	**20.946**

Contribution (%) from fishmeal from whole fish	4.439
Contribution (%) from fish oil from whole fish	0.312
Contribution (%) from fishmeal from byproducts	3.943
Contribution (%) from fish oil from byproducts	0.142
Contribution (%) from crop ingredients	91.164
Contribution (%) from land animal ingredients	0.000
Contribution (%) from other ingredients	0.000
Factor 5.3 score	**5**
C5 Final Feed Criterion Score	**5.5**
Critical?	**No**

Select species again Shrimp

Criterion 6: Escapes	**Data and Scores**
F6.1 System escape risk	4
Percent of escapees recaptured (%)	0.000
F6.1 Recapture adjustment	0.000
F6.1 Final escape risk score	4.000
F6.2 Invasiveness score	4
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	-2
System score if multiple species assessed together	n/a
C9X Wildlife Mortality Final Score	**-2**
Critical?	No

Shrimp

Criterion 10X: Introduction of Secondary Species	**Data and Scores**
Production reliant on transwaterbody movements (%)	0
Factor 10Xa score	10
Biosecurity of the source of movements (0-10)	10
Biosecurity of the farm destination of movements (0-10)	10
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