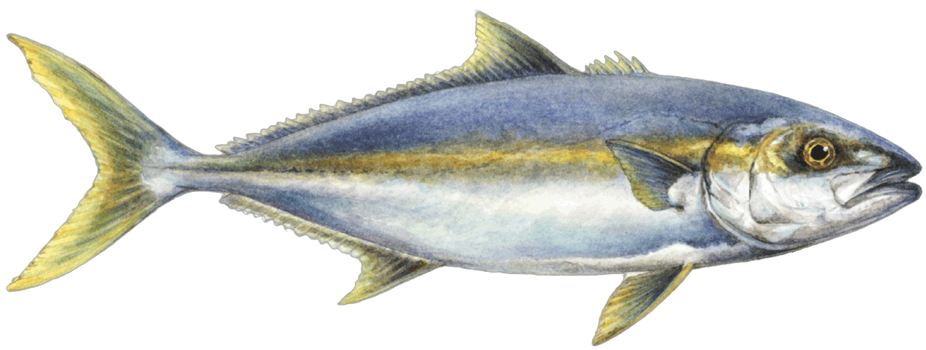
Environmental sustainability assessment of farmed Almaco jack *(Seriola rivoliana)* and Yellowtail *(Seriola lalandi)* from Mexico farmed using marine net pens.



Species: Almaco jack *(Seriola rivoliana)*, Yellowtail *(Seriola lalandi)*

Location: Mexico

Gear: Marine net pen

Type: Farmed

Author: Seafood Watch

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Assessed using Seafood Watch Aquaculture Standard v3.1

Final Seafood Recommendation

Yellowtail (*Seriola lalandi (dorsalis)* and *Seriola rivoliana)* from Mexico farmed in net pens

Criterion	Score	Rank	Critical?
C1 Data	7.50	GREEN	
C2 Effluent	7.00	GREEN	NO
C3 Habitat	6.53	YELLOW	NO
C4 Chemicals	6.00	YELLOW	NO
C5 Feed	5.11	YELLOW	NO
C6 Escapes	7.00	GREEN	NO
C7 Disease	5.00	YELLOW	NO
C8X Source	-2.00	GREEN	NO
C9X Wildlife mortalities	-2.00	GREEN	NO
C10X Escape of secondary species	-0.00	GREEN	
Total	**40.14**		
Final score (0-10)	**5.73**		

OVERALL RANKING

Final Score	5.73
Initial rank	YELLOW
Red criteria	0
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

Scoring note – scores range from 0 to 10, where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Criteria 8X, 9X, and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects a very significant impact. Two or more Red criteria result in a Red final result.

Summary

The final score for Mexican yellowtail produced in marine net pens is 5.73 out of 10 which is in the yellow range and with no red criteria, the final recommendation is a "Good Alternative".

Executive Summary

Two species of yellowtail pelagic jack, *Seriola lalandi* (*dorsalis)* and *Seriola rivoliana*, are produced in marine net pens on Mexico's west (Pacific) coast. As a young industry that began in 2007, production volumes from the three producers are still low, growing from 49 metric tons (MT) in 2014 to 336 MT in 2017. Further growth is expected with an increasing demand for its sushi and sashimi-grade product in the United States, Canada, Mexico, Japan, and the Middle East.

This Seafood Watch assessment involves criteria covering impacts associated with effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability.

Data: The yellowtail aquaculture industry in Mexico provided a significant amount of information for this assessment, including monitoring data, operations manuals, purchase records, communication records, environmental impact assessments, licensing documents, and other insights. Publicly available data are very limited and contacting regulators across several Mexican agencies to seek verification and additional information was challenging. The body of peer-reviewed literature on cultivation of this species in Mexico is limited but complemented by literature on similar production of congeneric species in other countries. Conference presentations, student theses, government publications, and government and industry websites are all useful resources for this assessment. Overall, the availability and quality of data is moderate to high. The score for Criterion 1 – Data is 7.5 out of 10.

Effluent: Despite the direct discharge of effluent wastes to the surrounding waterbody, Mexican yellowtail producers use modern operating conditions broadly recognized as being effective at minimizing the impacts of effluent from net pen operations. Official data on water quality are not publicly available, and data provided by the producers are somewhat limited. The available data show no evidence that effluent discharge is causing or contributing to cumulative impacts at waterbody or regional scales, nor beyond the immediate vicinity of the farm. Studies of potential impacts from yellowtail farm effluent in other regions (except for Japan) have also not demonstrated significant impacts and support the conclusion that effluent impacts can be minimized by strategic farm siting and operation protocols. The current scale of the industry in Mexico is likely to be a factor in the limited potential for cumulative impacts. With some uncertainty in the completeness of the data, Criterion 2—Effluent scores 7 out of 10.

Habitat: Seabed monitoring of Mexican sites has thus far not indicated measurable benthic impacts, though the specific data provided for this assessment are limited. Studies of yellowtail production internationally (except for Japan) have suggested minimal benthic impacts when properly sited and managed, and Mexican siting and management is consistent with such guidelines. This assessment concludes that Mexican yellowtail farming has minor impacts to the benthic environment, which are not leading to significant loss in habitat functionality. Factor 3.1 scores 8 out of 10. Mexico's habitat management approach contains some area-based and ecosystem functionality considerations, though how cumulative impacts are considered and whether future expansion is addressed accordingly is questionable. The score for Factor 3.2a is 3 out of 5. The Mexican industry has provided some evidence (monitoring data and reports) that suggest enforcement and compliance with regulations; enforcement organizations are identifiable and contactable and appear to be active in enforcing some aquaculture regulations but may have some limitations that reduce effectiveness. The score for Factor 3.2b is 3 out of 5. The final score for Criterion 3 – Habitat is 6.53 out of 10.

Chemicals: Mexican yellowtail production has an apparently low need for antibiotics: all three producers state that they either use no antibiotics or have not yet had a need to. Florfenicol may be maintained on-hand for occasional treatment of *Streptococcus* infections in stressed juvenile fish following out-planting to net pens but has not yet been used. The apparent low need for antibiotics is evident in yellowtail production elsewhere, but the data are challenging to verify. Mexican yellowtail production makes regular use of parasiticides—including Praziquantel (to manage internal parasites in incoming broodstock and occasionally to control skin flukes in fingerlings recently transferred to offshore sites) and hydrogen peroxide (for treatment of external skin fluke parasites at net pen sites). Praziquantel is used infrequently and its use is not considered a risk to human or environmental health. As hydrogen peroxide quickly dissociates upon contact with seawater, it is also considered a low environmental risk. The regular use of these pesticides is a low-moderate concern and the final score for Criterion 4 – Chemical Use is 6 out of 10.

Feed: Mexican yellowtail feeds use fishmeal (36.7% inclusion) and fish oil (12.4% inclusion) as feed ingredients with substantial use of byproduct sources. The Forage Fish Efficiency Ratio (FFER) is 1.48 and the marine ingredients are sourced from sustainable fisheries; the Wild Fish Use score is 5.72 out of 10. The total feed protein content is approximately 45%, increasingly being supplied by crop-based ingredients. There is an estimated 46.7% net loss in edible protein during production and a moderate feed footprint. The final score for Criterion 5 – Feed is 5.11 out of 10.

Escapes: Net pens, as open systems, represent an inherent risk of escape by farmed stock due to operational failures and human error. Mexican producers have reported trickle losses and isolated escape events (up to 1500 fish) but have apparently not experienced a major escape event (defined as >5% of the holding unit stock). Producers minimize escapes using management measures including daily monitoring, use of high-quality construction materials (e.g., copper alloy nets), and installation of net coverings; nevertheless, the reported failures and human errors demonstrate that the risk of escape must be considered moderate and Factor 6.1 Escape Risk scores 4 out of 10. The known escape events have been reported (by the producers) to also have high recapture rates of between 47 to 95% which increases the Escape Risk score to 7 out of 10. Both species of farmed *Seriola* yellowtail cultivated in Mexico are native to the region of production. Hatcheries make use of locally caught broodstock, replacing a portion of total broodstock with new adults annually to refresh the hatchery's gene pool. As such, Mexican farmed yellowtail are native and likely of high genetic similarity to their wild conspecifics, representing low risk of impact should a large escape occur. Factor 6.2 scores 8 out of 10 and the final score for Criterion 6 – Escapes is 7 out of 10.

Disease: Since the quality and availability of disease data is moderate (i.e., Criterion 1 score of 5 out of 10 for the disease category), the Seafood Watch risk-based assessment was used. The *Seriola* genus generally has low susceptibility to disease in current culture conditions; however, the small scale of the current industry may be a factor. Like many aquaculture settings, the higher densities of farmed fish present some challenges to fish health and in Mexico, parasite issues (*Neobenedenia* and *Heteraxine* skin and gill flukes) are the primary concern. Net pens are open to the surrounding environment and therefore to the exchange of pathogens and parasites from wild fish to farmed fish and vice versa. High survival rates typical of Mexican yellowtail production correspond with low disease-related mortalities, but parasite numbers are substantial as indicated by average and peak prevalence and the regular use of pesticides. The monitoring of wild fish in Mexico is limited, and while monitoring at a similar farm in Hawaii does not indicate the transmission of parasites from the farm to wild fish, these results cannot confidently be used to assume there is a similar lack of transmission at the sites covered in this assessment in Mexico. As such, there remains a concern regarding the open nature of the production system and the discharge or pathogens and parasites. The final score for Criterion 7 – Disease is 5 out of 10.

Source of Stock: Only small numbers of wild-caught broodstock are used annually to supply hatcheries producing eggs and juveniles, and there is no use of wild-caught juveniles. With only partial replacement of broodstocks, 28% of Mexico's yellowtail production is considered to be dependent on wild broodstock from a source that has greater than minimal sustainability concern. This equates to a final score for Criterion 8X Source of Stock of –2 out of –10.

Predator and Wildlife Mortalities: Mexican yellowtail farms are located in regions rich in wildlife. Consistent with Mexican law, producers make use of non-lethal deterrents such as top netting, rigid mesh, regular monitoring, and prompt removal of fish mortalities. Wildlife interactions are apparently limited to non-lethal "curiosity" visits and occasional scavenging of mortalities by pinnipeds. The relevant species are not of current conservation concern. Mexican law additionally protects marine mammals and any incidental mortalities come with reporting requirements (although no data are publicly available). Although no wildlife mortalities associated with Mexican yellowtail production have been reported by the farms, given that the occurrence of occasional entanglements is similar to net pen aquaculture systems globally, the potential for unobserved or unreported mortalities exists; absent further verification, this assessment concludes that wildlife and predator mortalities may occur in exceptional cases. The final score for Criterion 9X – Wildlife Mortalities is –2 out of –10.

Escape of Secondary Species: Mexican yellowtail fingerlings are produced in modern, domestic hatcheries, and do not require imports or trans-waterbody shipments of live fish or eggs. As such, risk of escape of unintentionally introduced species with this industry is low. The final score for Criterion 10X – Escape of Secondary Species is –0 out of –10.

The final score for Mexican yellowtail produced in marine net pens is 5.73 out of 10 which is in the yellow range and with no red criteria, the final recommendation is a "Good Alternative."

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Scope of the analysis and ensuing recommendation

Species
Yellowtail, or *Seriola* jacks, *Seriola lalandi (synonymized as Seriola dorsalis)* and *Seriola rivoliana*

Geographic Coverage
Mexico

Production Method(s)
Floating and submersible net pens.

Species Overview

Brief Overview of the Species
The name "yellowtail" refers to a number of congeneric jack species in global aquaculture production. Two species of *Seriola* jack are cultured in Mexico and marketed as yellowtail, Kampachi, Kanpachi, or Hiramasa: *Seriola lalandi* (*dorsalis*[1]*)* and *Seriola rivoliana.* For simplicity, this assessment refers to both species as "yellowtail" or by their binomial (scientific names).

S. lalandi, or California yellowtail, is a coastal pelagic (and sometimes demersal) species of jack with a global distribution in subtropical and temperate regions. It is native to the Mexican Pacific and Gulf of California waters in which it is farmed, and the species is a valued commercial and recreational fisheries target (Swart 2014) (Martinez-Takeshita et al. 2015). *S. rivoliana*, or Almaco jack, is also a predatory jack species native to Mexican waters, with an overall Pacific range from the United States (Hawaii and southern California) to Peru (Quiñones-Arreola *et al.* 2015) (Fishbase.se). Like most species of the Carangidae family, *S. lalandi and S. rivoliana* are fast-swimming predatory fish that hunt in the open sea or the waters surrounding reefs, found in small schools or solitary (Swart 2014). Juveniles associate with drifting seaweeds (Kolkovski and Sakakura 2004).

Rapid growth, adaptability to captivity, and high market value make both *S. lalandi* and *S. rivoliana* attractive and emerging aquaculture species in Mexico (Quiñones-Arreola et al. 2015).

Production System
At least 4 congeneric *Seriola* species, all marketed as yellowtail, are produced globally in several variations of similar production systems in Japan, Australia, Chile, Hawaii, Europe, and New Zealand (Kolkovski and Sakakura 2004) (Symonds et al. 2014) (Purcell et al. 2015) as well as Mexico. Globally, yellowtail production began as a sea-ranching production system (growing

[1] *Seriola lalandi* from the NE Pacific has been proposed by Purcell et al. to be named S. dorsalis (Purcell et al. 2015). At the time of writing, *Seriola lalandi* remains the accepted term (WoRMS 2019) and is used herein.

wild caught juveniles to harvest size) in 1950s Japan, but has evolved with its international growth (Benetti et al. 2016). Closed life-cycle (hatchery based) production of yellowtail has become a critical part of the growth of this sector (Purcell et al. 2015).

Mexican production of yellowtail began in 2007 (F. Rotman, Hubbs Seaworld Research Institute, pers. comm. 2019) (Astiazaran et al. 2016), with research into viability beginning as early as 2004 (Aviles-Quevedo and Castello-Orvay 2004). There are currently three companies in Mexico marketing their product as yellowtail, kampachi, kanpachi, or hiramasa. All production is in Baja California Sur, with one operation in the Pacific (Bahia Magdalena) and two in the Gulf of California; three other existing concessions are not yet active (INAPESCA 2018a).

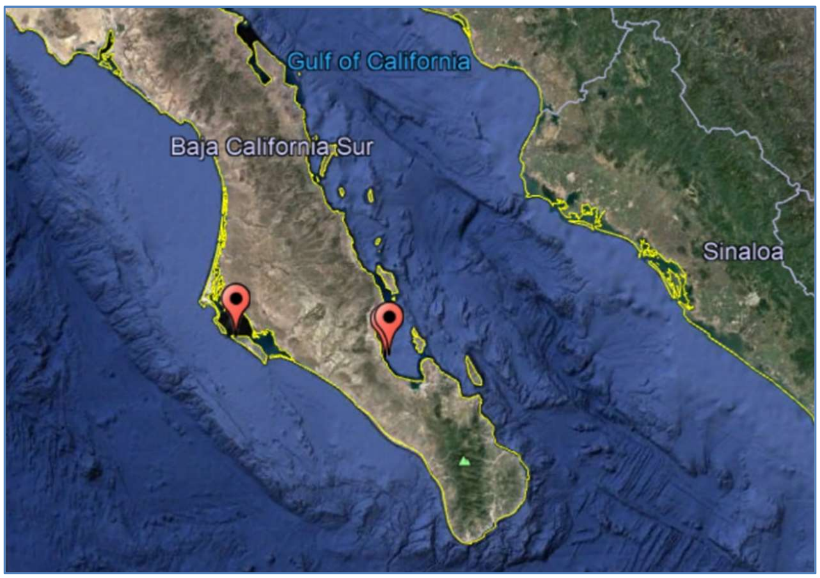

Figure 1. Seriola farm locations in Baja California Sur, Mexico. Pacific coast site is in Bahia Magdalena and Gulf of California sites are located within Bahia La Paz. Image from Google Earth.

Yellowtail fingerlings are produced in closed, recirculating and/or high-biosecurity hatchery facilities in Baja Mexico (each farm has their own modern hatchery), and are grown out to harvest size in floating ocean net pens (Figure 2) (Astiazaran et al. 2016) or submersible cages (Sims and Vollbrecht 2019) located approximately 4 miles offshore (King Kampachi 2019). Net pens (Figure 2, 3) are typically about 12 to 25 m in diameter and 4 to 8 m deep (Kolkovski and Sakakura 2004) (INAPESCA 2018b), situated over depths of 20 m to 60 m in waters protected from winds and swell, and with moderate currents (INAPESCA 2018b) (N. Sims, King Kampachi pers. comm. 2019).

Net pen lease areas are about 300 hectares (ha), within which net pens could be moved if desired to fallow production areas. Growout from fingerling to market-sized requires the provision of commercial feeds and is rapid, with 1.5 kg achievable in 6 to 8 months of growout (Aquaculture North America 2014). The production cycle (including the hatchery phase) is about 8 to 16 months, with typical growout at about 6 to 14 months, depending on temperature and species (INAPESCA 2018b) (Omega Azul 2018) (King Kampachi 2019) (J. Morris pers. comm. 2019) (F. Rotman, pers. comm. 2019).

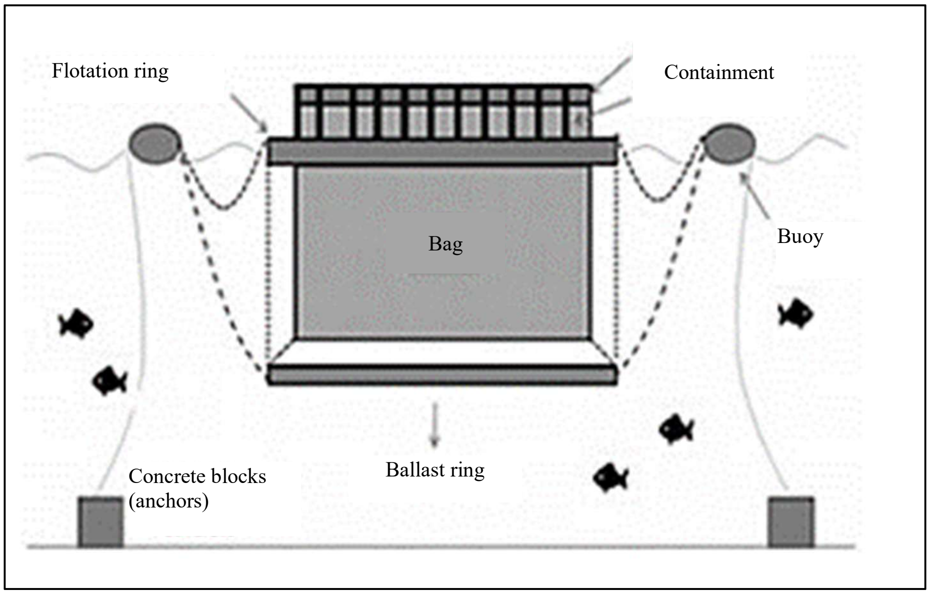

Figure 2. Example of a floating Mexican net pen design. Adapted from (INAPESCA 2018b).

Figure 3. Net pens at a Mexican S. rivoliana farm. Photo: (King Kampachi 2019).

This assessment focuses on the growout portion of the production cycle, which in Mexico occurs entirely in floating and submersible net pens. For convenience, all growout designs will be referred to as "net pens" in the text of this assessment, unless there is a reason for distinction.

Production Statistics

Mexico currently has three active producers of yellowtail—all in Baja California Sur—and with additional concessions and permits issued for Baja California and Sonora (Chavez Garcia 2016). Mexican yellowtail production is reported by the FAO under an aggregated general "jacks" category, with the most recent production totals reported (2017) at 336 MT. Data on the current proportions of the two species produced in Mexico was not available. The Mexican government (CONAPESCA[2]) has overall production data available through 2014 only, with more recent data unavailable (attempts to contact CONAPESCA for more recent information did not receive a response). One producer's website states 2015 production as 70 MT (Baja Seas Aquaculture 2018) and another producer estimated their 2017 production as 181.4 MT, double the year previous (Omega Azul, pers. comm 2017). A third company expanded from Hawaii, beginning production in Mexico in June 2018. It is evident that this is a growing industry in Mexico.

Table 1. Annual aquaculture production, Mexican yellowtail (FAO 2019)

	2014	2015	2016	2017
Production (MT)	49	131	222	336
Value (x1000 USD)	34	1,367	2,677	4,684

Import and Export Sources and Statistics

The primary market for Mexico-produced yellowtail is the United States with significant local sales in-country, and some outlet to Europe, the Middle East (Aquaculture North America, 2014), and Japan (INAPESCA 2018a).

US imports of *Seriola* spp. are not monitored by the NOAA Office of Science and Technology, indicating that it is not imported or exported in large quantities. Statistics for farmed *Seriola* spp. Mexican exports to the US could not be parsed from overall *Seriola* spp. exports which include wild-capture (FAO 2017).

One company provided information regarding their exports to the US: in 2017, Omega Azul estimated exporting nearly 150 MT to the US This is equivalent to 82.5% of their expected production of 181.4 MT and an increase from the previous year when 38.1 MT out of 90.7 MT, or 42% of total production, was exported to the US. The company indicated that the remainder of their product is sold in Mexico and Canada (Omega Azul, pers. comm. 2017).

Common and Market Names

Scientific Name	*Seriola lalandi (dorsalis)*	*Seriola rivoliana*
Common Name	Yellowtail, California yellowtail, yellowtail kingfish, yellowtail jack, yellowtail amberjack, horse mackerel	Almaco jack, Pacific yellowtail, long-fin yellowtail, long-fin Mexican amberjack

[2] CONAPESCA - Comisión Nacional de Acuacultura y Pesca. https://www.gob.mx/conapesca

Spanish	*jurel cola amarilla, jurel de castilla, jurel de California, medregal amarillo, medrigal cola amarilla*	*Pez fuerte, medregal limón, medregal almaco*
Market name	Yellowtail, Hiramasa, Baja Hiramasa	Kampachi, King Kampachi, Baja Kanpachi

Product forms
Yellowtail is produced for the sushi and sashimi markets and most often appears raw; it also appears on the plate as crudo and pan-seared and may also be grilled, poached, smoked, or cured. It is typically shipped as whole fish, filets, fresh or frozen.

Analysis

Scoring guide

- With the exception of the exceptional criteria (8X, 9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rating. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the three exceptional criteria result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Standard that the following scores relate to are available on the Seafood Watch website. http://www.seafoodwatch.org/-/m/sfw/pdf/standard%20revision%20reference/mba_seafoodwatch_aquaculture%20criteria_finaldraft_tomsg.pdf?la=en

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 publicly available.

Criterion 1 Summary

Data Category	Data Quality	Score (0-10)
Industry or production statistics	7.5	7.5
Management	7.5	7.5
Effluent	7.5	7.5
Habitat	7.5	7.5
Chemical use	5	5
Feed	7.5	7.5
Escapes	7.5	7.5
Disease	7.5	7.5
Source of stock	10	10
Predators and wildlife	5	5
Introduced species	10	10
Other – (e.g. GHG emissions)	Not Applicable	n/a
Total		**82.5**

C1 Data Final Score (0-10)	**7.5**	**GREEN**

Brief Summary

The yellowtail aquaculture industry in Mexico provided a significant amount of information for this assessment, including monitoring data, operations manuals, purchase records, communication records, Environmental Impact Assessments, licensing documents, and other insights. Publicly available data are very limited and contacting regulators across several Mexican agencies to seek verification and additional information was challenging. The body of peer-reviewed literature on cultivation of this species in Mexico is limited but complemented by literature on similar production of congeneric species in other countries. Conference presentations, student theses, government publications, and government and industry websites are all useful resources for this assessment. Overall, the availability and quality of data is moderate to high. The score for Criterion 1 – Data is 7.5 out of 10.

Justification of Rating

The yellowtail aquaculture industry in Mexico provided a significant amount of information for this assessment, primarily from two producers who are cited (one chose to remain anonymous) throughout this report. Numerous attempts to contact Mexican government agencies and institutions—including CONAPESCA, PROFEPA, SAGARPA, SENASICA, CESABCS, and CIBNOR, were largely unsuccessful in achieving responses. Of the two species assessed here, the literature associated with the culture of *Seriola lalandi (dorsalis)* is more advanced than that of *Seriola rivoliana*; as such, there is more information available regarding the former species. Species specifics are noted where relevant, but in general, this assessment assumes that the two species and their cultivation methods do not differ significantly.

Industry and Production Statistics

Mexican farmed yellowtail production data through 2017 are available from the Food and Agriculture of the United Nations (FAO), but the Mexican government (CONAPESCA) has only production data through 2014 available. All three companies farming yellowtail in Mexico have provided information either directly or indirectly via their websites, and industry publications also provide some production information. Information on production methods (both in Mexico and elsewhere) is available in the scientific and gray literature (Aviles-Quevedo and Castello-Orvay 2004) (Kolkovski and Sakakura 2004) (Symonds et al. 2014) (Purcell et al. 2015) (Benetti et al. 2016) (Sicuro and Luzzana 2016), in industry publications, in conference presentations, and on company websites. Farm location information is readily available in government, industry, and company publications. The data score for Production Statistics is 7.5 out of 10.

Management and Regulations

Federal regulations are available on government websites and some data are available for download, for example through CONAPESCA. Mexican state governments, including their aquaculture health committees also provide some useful information on regional specifics. Environmental Impact Assessments are publicly available.[3] Producers also provided information useful to this assessment—including copies of permits, communications with regulators, and more. Information on enforcement is lacking in detail and difficult to draw conclusions from. The published literature contains some helpful reviews of Mexican regulation e.g., (FAO 2009) (Perevochtchikova and André 2013) (Sosa-Villalobos et al. 2016) (Mellink and Riojas-López 2017). The data score for Management and Regulations scores 7.5 out of 10.

Effluent: Some effluent-related information was provided by industry, including sediment and water quality monitoring data from parts of 2017 to 2019, and records of communication with regulatory agencies. Supplied data, however, are variable in completeness; for example, there are gaps in the sampling year for both datasets provided for this assessment. Production of yellowtail in similar systems in other countries provides some additional information relevant to this assessment, including data on monitoring of effluent and impacts. A Hawaiian farm for example, provides monitoring reports on its website, and Australia and Japan have various publications exploring yellowtail effluent issues. There is a substantial volume of literature on similar production systems for other species and for net pen aquaculture in general. There are

[3] http://sinat.semarnat.gob.mx/dgiraDocs/documentos/bcs/resumenes/2008/03BS2008PD098.pdf
http://sinat.semarnat.gob.mx/dgiraDocs/documentos/bcs/estudios/2012/03BS2012PD031.pdf

also some publications on the oceanography and hydrology of the bodies of water hosting Mexican yellowtail production. Regulating agencies are identifiable and contactable, effluent regulations are readily available, and some coarse enforcement data are available, although its applicability to yellowtail farming is unclear. Information on enforcement activities and compliance was also not verifiable. Although specific data are somewhat limited, overall, the data score for Effluent is 7.5 out of 10.

Habitat
Mexican producers provided information for this assessment—including descriptions of monitoring programs, benthic and water quality monitoring reports, and copies of permits etc. Further information is available from environmental impact assessments and industry publications. Information on production of *Seriola* species in other countries was also useful at advising this assessment—such as Hawaii, from which benthic monitoring data and reports are available for comparison. Regulating agencies are identifiable and contactable, and some coarse enforcement data is available. Attempts to contact regulators for additional information and verification were unsuccessful. The data score for Habitat scores 7.5 out of 10.

Chemical Use
Producer websites, industry publications, and personal communication with producers provided information relevant to this assessment. Information on production of *Seriola* species in California, Hawaii, Japan, and Australia was also useful. Industry contacts provided specific information on their use of chemicals as well as copies of permits, purchase records, application records, veterinary qualifications, and other relevant documentation; two third-party experts familiar with the industry provided additional information. Information on disease prevalence and mortality rates also supported this criterion. Regulatory information is available on government websites and regulatory personal communications provided some information, though level of enforcement is unclear. With a reliance on industry reported data for specific chemical uses in Mexico, the data score for Chemical Use is 7.5 out of 10.

Feed
Mexican Yellowtail producers provided specific feed formulation information from both feed providers supplying the industry (Skretting and EWOS). One major feed producer provided additional feed ingredient information. eFCR values were provided by two companies, one of which also provided data used in calculating their eFCR values. Additional information was available via scientific publications related to research on feeds, fish nutrition, eFCR values, protein content and compositions, and more; and through the websites of both providers of feeds for this industry. Although the data availability was good, it did not relate robustly to all of the Mexican yellowtail production; therefore, the data score for Feed is 7.5 out of 10.

Escapes
Yellowtail escapes in Mexico must be reported to the relevant authorities, but there are no official data, and only one company provides publicly available information on escape events,

recaptures and the company's response.[4] Assessing genetic risk of escapes is supported by scientific research into population structure for S*. lalandi*, but not *S. rivoliana*. There are useful reports from other regions, particularly Hawaii. Mexican producers also provided information on broodstock collection, breeding, containment, and escape and recapture of fish. Although specific escape and recapture data are limited and challenging to verify, the nature of the native species and information on broodstock management result in a data score for Escapes of 7.5 out of 10.

Disease

The scientific literature features extensive publication on disease and parasite issues for yellowtail production in other regions of the world e.g. (Chambers and Ernst 2005) (Hutson 2007) (Nakada 2008) (Abo et al. 2013) (Sepúlveda and González 2015) (Sicuro and Luzzana 2016) (Bravo et al. 2017), with useful industry publication available also (Sims 2013). Some information on fish parasites of Mexican waters is also available in the scientific literature (Aviles-Quevedo and Castello-Orvay 2004) (Trasviña-Moreno et al. 2017) (Vivanco-Aranda et al. 2019), and is supplemented by government publications and conference presentations, though baseline data on parasite presence in wild Mexican fish and studies examining transmission of parasites between wild and farmed Mexican fish are absent. Industry also provided information useful to this assessment—including biosecurity protocols and details on fish health management, as well as parasite prevalence data from 2018 and 2019. Two third-party experts also provided relevant information on disease and parasite management from North American yellowtail production. Overall, there is limited data on parasite prevalence in wild fish, and on cultured-to-wild fish transmission of pathogens. The data score for Disease is 5 out of 10.

Source of Stock

Industry publications, company websites, conference presentations, and the scientific literature provide information on Mexican yellowtail hatcheries supplying the industry, as well as on breeding. There is additional information from similar production systems elsewhere in the world that is also useful to this assessment. The data score for Source of Stock is 10 out of 10.

Wildlife and Predator Mortalities

The scientific literature describing the wildlife present in the area of production is ample but specific information on wildlife-aquaculture interactions with yellowtail farms is sparse. Some industry reports on farmed yellowtail and wildlife interactions from a Hawaiian farm are available, as are some industry and scientific publications from Australia and New Zealand, and from similar net pen systems globally. The industry provides information on their predator exclusion measures on their websites and provided additional information on wildlife interactions through interview. The industry also provided copies of wildlife management protocols, copies of permits and an environmental impact assessment, and copies of both reporting forms and some actual reports from 2018. Relevant government regulations are also readily obtainable, but no official data are available. Two third-party experts familiar with North American yellowtail aquaculture also provided some information on wildlife interactions, but

[4] https://kingkampachi.mx/monitoring-and-reporting/performance-metrics/#1553817550412-3271092d-4b29

specific data remain limited, and the potential for undetected or unreported mortalities exists. The data score for Wildlife and Predator Mortalities is 5 out of 10.

Escape of Secondary Species

Industry publications, company websites, conference presentations, and the scientific literature provide information on yellowtail hatcheries supplying the industry, including on biosecurity. Two industry producers also provided information relevant to this criterion directly. The data score for Escape of Secondary Species is 10 out of 10.

Conclusions and Final Score

The yellowtail aquaculture industry in Mexico provided a significant amount of information for this assessment, including monitoring data, operations manuals, purchase records, communication records, environmental impact assessments, licensing documents, and other insights. Publicly available data are very limited and contacting regulators across several Mexican agencies to seek verification and additional information was challenging. Two producers provided information for this assessment and are cited (one chose to remain anonymous) throughout this report. Several knowledgeable third-party experts also provided information for this assessment. The body of peer-reviewed literature on cultivation of these species in Mexico is limited but complimented by literature on similar production of congeneric species in other countries. Conference presentations, student theses, government publications, and government and industry websites are also useful resources for this assessment. Overall, the availability and quality of data is moderate to high. This criterion scores 7.5 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 Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**7**	**GREEN**

Brief Summary

Despite the direct discharge of effluent wastes to the surrounding waterbody, Mexican yellowtail producers use modern operating conditions broadly recognized as being effective at minimizing the impacts of effluents from net pen operations. Official data on water quality are not publicly available, and data provided by the producers are somewhat limited. The available data show no evidence that effluent discharge is causing or contributing to cumulative impacts at waterbody or regional scales, nor beyond the immediate vicinity of the farm. Studies of potential impacts from yellowtail farm effluent in other regions (except for Japan) have also not demonstrated significant impacts and support the conclusion that effluent impacts can be minimized by strategic farm siting and operation protocols. The current scale of the industry in Mexico is likely to be a factor in the limited potential for cumulative impacts. With some uncertainty in the completeness of the data, Criterion 2 – Effluent scores 7 out of 10.

Justification of Rating
As effluent data quality and availability is good (i.e., Criterion 1 score of 7.5 or 10 of 10 for the effluent category), the evidence-based assessment was used.

The Seafood Watch Effluent Criterion considers impacts of farm wastes beyond the immediate farm area or outside a regulatory allowable zone of effect (AZE; defined by Seafood Watch as beyond 30 m of the farm), and the subsequent Habitat Criterion considers impacts within the immediate farm area. Although the two criteria cover different impact locations, there is inevitably some overlap between them in terms of monitoring data, scientific studies, management, and regulation. Much of this information will be presented in this Effluent Criterion, with the intent of minimizing (but not entirely avoiding) repetition in the Habitat Criterion.

S. lalandi retains only 14 to 15% of nitrogen from feeds (this is 6 to 25% lower than salmonids, for example), excreting the rest as waste, mostly (70 to 72%) in dissolved form (Tanner at al 2006). Particulate waste, such as fecal matter, represents about 15% of effluent lost to the environment and is a major source of nitrogen export away from the farm site. Due to high feed costs, avoiding or minimizing uneaten feed loss is a priority for farms, and any losses are likely to accumulate locally, under the net pen sites (Tanner et al. 2006).

In addition to instituting a number of conditions on the operation of Mexican yellowtail farms aimed at minimizing impacts of farm effluent, Mexican regulators, including the National Fisheries Institute (INAPESCA) and the Navy require monitoring of water and sediment quality associated with farm effluent in permitting issued by SAGARPA—including for total suspended solids (TSS), nitrates, biological oxygen demand (BOD), turbidity, total phosphorus, total nitrogen (TN), benthic diversity, and more (Anonymous 2019a, 2019b) (SEMARNAT 2014a, 2014b). Analysis is conducted by a certified laboratory and results are submitted to SEMARNAT (SEMARNAT 2018).

Yellowtail producers have stated that no measurable impacts associated with current production have been observed (T. Morris, pers. comm. 2019) (The Kampachi Company 2018), and the *Centro de Investigaciones Biológicas del Noroeste S.C.* (CIBNOR, a government research institution involved with monitoring at one farm) provided confirmation that at least for one farm, no measurable impacts from effluent have been observed (H. Villarreal, CIBNOR, pers. comm. 2019). Attempts to reach SEMARNAT for additional verification, which would be more representative of the industry overall, were unsuccessful. Two companies provided some temporally limited data on effluent monitoring; Figure 4 shows total phosphorous results and Figure 5 shows BODs. Similar data for total nitrogen (not shown) indicate that levels of all monitored parameters at the site and down-current were far below regulatory limits (including BOD, TP, and TN), and not significantly different from the reference site or pre-production baseline used (Anonymous 2019b) (T. Morris, pers. comm. 2019). Additional metrics analyzed, such as benthic diversity indices measured downstream of the sites, have also thus far demonstrated no significant signals of ecological impact (see Criterion 3 – Habitat). It must be noted that the provided data is limited in time (e.g., parts of the year), and limited in coverage of complete production cycles (one site had only just started production in June, 2018). Together, these factors make broad conclusions based on the data somewhat tenuous.

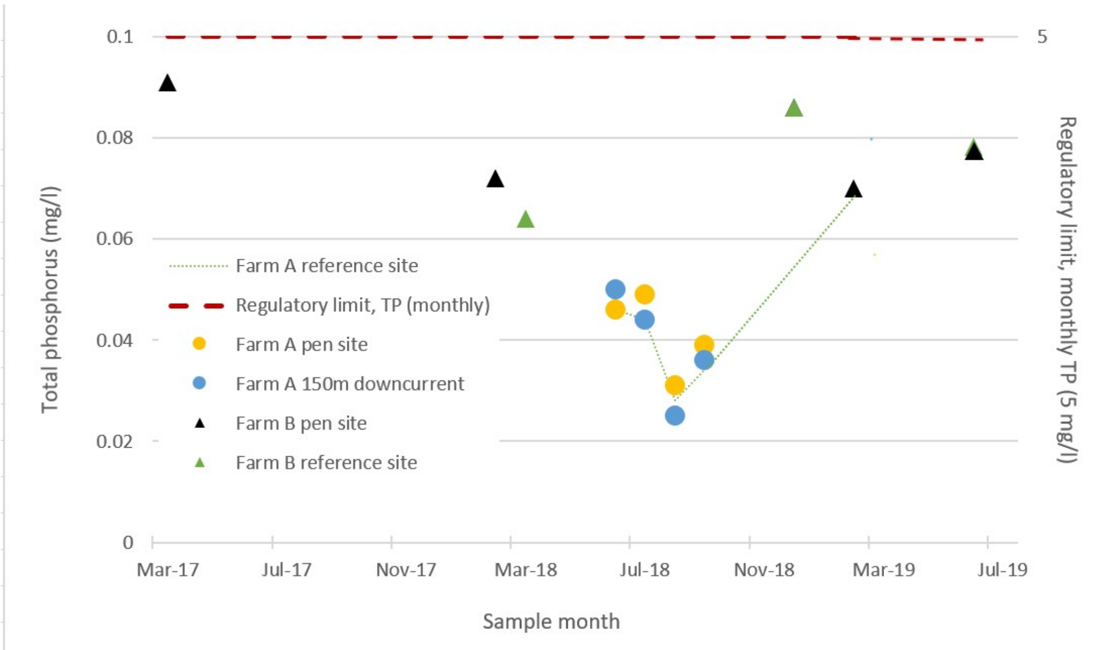

Figure 4. Results of benthic total phosphorus (TP) monitoring at two farm sites, 2017 to 2019. Samples collected during this timeframe at Farm A were well below regulatory limits, with no significant difference between samples collected under the farm site, downstream of the farm site, and a reference area. All samples at Farm B were well below the regulatory limit. Industry-provided data. Data: (Anonymous 2019) (T. Morris, pers. comm. 2019).

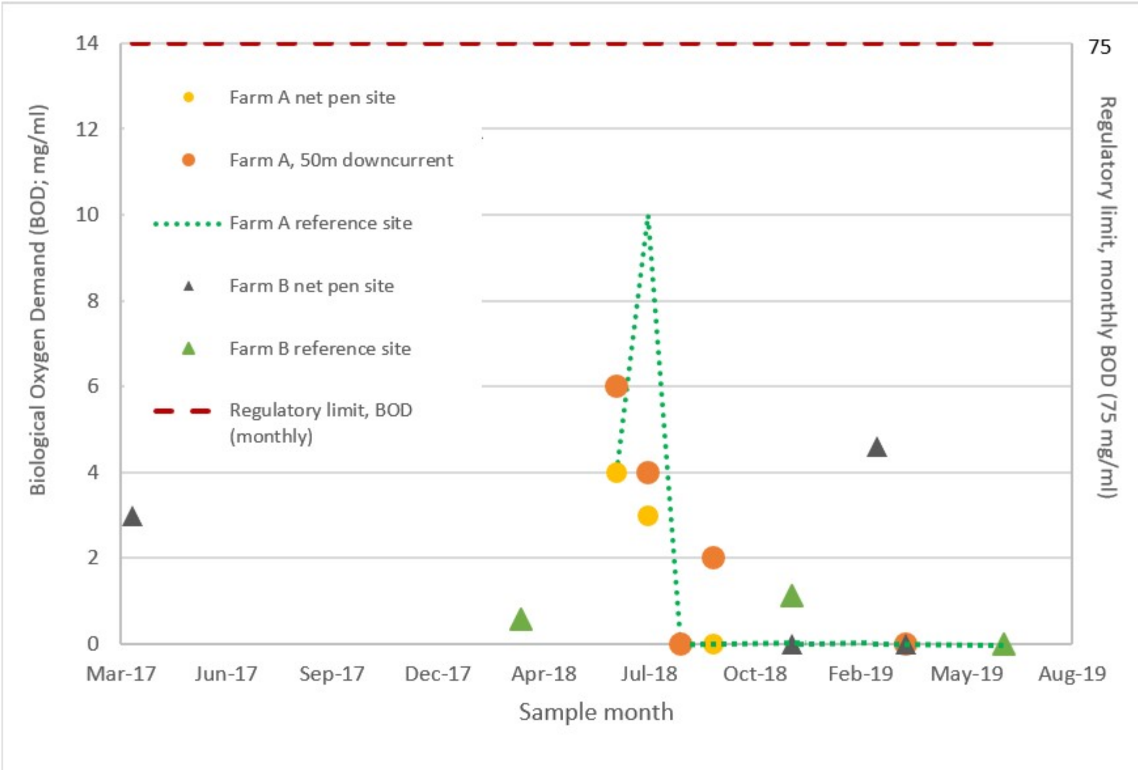

Figure 5. Results of benthic biological oxygen demand (BOD) monitoring at two farm sites, 2017 to 2019. Samples collected for Farm A during this timeframe were well below regulatory limit for BOD, with no significant difference between samples collected under and downstream of the farm site and a reference site. Samples collected at Farm B were also well below the regulatory limit. Industry-provided data. Data: (Anonymous 2019) (T. Morris, pers. comm. 2019).

Although these incomplete datasets offer limited certainty, they do provide some useful information and indicate compliance with monitoring and reporting requirements. Monitoring results are intended to inform whether floating aquaculture operations are having impacts to ecological conditions and functioning around and beneath the installations. Regulatory feedback to observed impacts includes requirements to adjust location, orientation, and spacing of net pen installations. One producer stated that as no significant impacts have been observed, there has not yet been a need for corrective actions (J. Morris, pers. comm. 2019) and CIBNOR states that, currently, cage siting and management are effective to minimize environmental impacts (H. Villarreal, pers. comm. 2019).

Information (including in the published literature) on effluents specific to Mexican yellowtail farming is limited; however, though some caution must be exercised in extrapolating the results from different locations to the circumstances in Mexico, some relevant resources from yellowtail production in other regions exist and additional literature on similar production systems, (e.g., cobia; see Seafood Watch 2015) is ample. For example, yellowtail farming in Japan (of *S. quinqueriadiata*) has received some research attention, including on effluent. Tanigawa et al. (2007) describe immediate and drastic increases in organic matter load (acid volatile sulfide, total phosphorus) to benthic sediments following the introduction of a yellowtail farm, but note these increases were limited to within 50 m of the farm; this is likely due to low current speeds and dispersion at sites in enclosed basins (Abo et al. 2013) and inland seas (Srithongouthai and Tada 2017).

In Australia, Tanner et al (2006) concluded minimal impacts to the benthic environment beneath *S. lalandi* farms, but likely transport away from farms due to dissolved nature and low settling velocity of much of the waste. Later work by Tanner and Fernandes (2010), found elevated levels of ammonia next to cages, but no evidence of increase in phytoplankton abundance, chl-a, nearby seagrass epiphyte biomass, or change in seagrass nutrient composition in proximity to cages. The authors suggest that soluble nitrogen waste (ammonia) is likely rapidly dispersed before being utilized; the site is characterized as of “relatively high” current velocities (which are likely less than those experienced on at least two of Mexico’s three sites (Bizzarro 2008) (Tanner and Fernandes 2010) (The Kampachi Company 2018). This study also found elevated levels of organic carbon and nitrogen content and porewater phosphorus but suggested that overall organic enrichment is “very low,” and failed to find any definitive indications of organic enrichment associated with the farm. The lack of obvious or significant effects is also attributed to the low production levels in the bay of study (Tanner and Fernandes 2010), which at the time of study was greater (up to 3.8x) than 2017 Mexican production.

Ammonia and turbidity are monitored monthly at a Hawaiian farm producing *S. rivoliana,* with additional parameters also monitored quarterly (N. Sims, pers. comm. 2019). Monitoring at times of peak production has concluded no measurable impact to water quality parameters between downstream sites and upstream controls. The same work has found no measurable impacts to benthic community structure either directly below or beyond the footprint of the cage site during routine production. Disturbance to sediment chemistry at the cage site has been limited to isolated episodes of anoxia that were resolved when a malfunctioning feeding system was repaired (Sims 2013).

There is a substantial additional body of literature on the physical, chemical, and biological implications of nutrient waste discharges from net pen fish farms in general, and key recent reviews such as Price et al. (2015) provide a useful summary. For example, Price et al. (2015) conclude that modern operating conditions have minimized impacts of individual fish farms on marine water quality; effects on dissolved oxygen and turbidity have been largely eliminated through better management, and near-field nutrient enrichment to the water column is usually not detectable beyond 100 m of the farm (when formulated feeds are used, feed waste is minimized, and farms are properly sited in deep waters with flushing currents). However, when sited nearshore, extra caution should be taken to manage farm location, size, biomass, feeding protocols, orientation with respect to prevailing currents, and water depth to minimize near- and far-field impacts. Price et al. (2015) do caution that regardless of location, other environmental risks may still occur; for example, significant questions remain about the cumulative impacts of discharge from multiple, proximal farms, potentially leading to increased primary production and eutrophication (Price et al. 2015).

Regulation and Management

An EIA for a proposed (now existing) farm in Bahia de Magdalena suggested that the primary environmental concerns associated with the farm would relate to impacts from uneaten feed and fish waste. The EIA suggested that, due to the hydrodynamic and oceanographic characteristics of the site, waste could be dispersed and assimilated so as to cause minimal impact—if measures were taken to manage feed inputs and stocking densities, and site net pens strategically (BioPesca 2008) (SEMARNAT 2012), which were instituted according to conditions of licensing.

Licensing in Mexico seeks to limit impacts via various strategies, such as reducing intensity of environmental impacts by establishing large areas for concessions so that pens may be sited with adequate spacing, and by dictating minimum spacing requirements (SEMARNAT pers. comm. 2014). Depth is also an important consideration in siting to minimize effluent impacts to the benthos, with depths of greater than 20 m recommended (Aviles-Quevedo and Castello-Orvay 2004), which is also part of siting in Mexico (INAPESCA 2018b). Mexican yellowtail farms are sited between 20 and 60 m of depth (SEMARNAT 2012 2014b). Mexico also considers underlying substrate type in seeking to limit benthic impacts with its siting guidelines (Aviles-Quevedo and Castello-Orvay 2004). Through conditions of permit, maximum stocking densities are also instituted (SEMARNAT, pers. comm. 2014).

Although effluent impacts have been observed associated with yellowtail aquaculture sites in Japan, these farms are often sited in enclosed basins (Abo et al. 2013) such as inland seas (Srithongouthai and Tada 2017). Studies of other yellowtail production sites, such as in open water or other high current velocity environments, have concluded minimal impact to benthic environments. Net pen effluent impacts to the benthos can be reduced significantly by siting in areas with mean current speeds of >7 cm/s and appropriate depth (Bannister et al. 2014) (Rust et al. 2014) and Mexico siting guidelines suggest a current speed of 50 cm/s as optimal for these purposes (Aviles-Quevedo and Castello-Orvay 2004). Information on average current speeds is not available for all sites, but current regimes at Bahia Magdalena, where one of Mexico's three yellowtail farms is sited, are described as "flushing suspended sediment and inhibiting sedimentary infilling processes," with current speeds reported to peak at 50 to 109 cm/s, depending on location. Although these speeds are not likely representative of all locations in the bay, they do suggest that this bay is adequately flushed and that this farm site is appropriately sited to promote dispersal of effluent wastes. An EIA for a farm site in Bahia de La Paz hypothesizes a similar conclusion, though it notes that specific understanding of the hydrodynamics of this bay is lacking and recommends pursuit of such study (SEMARNAT 2014a). Measured current speeds at a third site (also in Bahia de la Paz) peak at 35 cm/s (Kampachi Company 2018). It appears that all three of Mexico's farms are sited in areas with current speeds adequate to disperse wastes effectively.

Feed has long been recognized as a source of effluent pollution; as such, research into improved feeds for yellowtail farming has occurred since at least the early 2000s (Satoh et al. 2004). The Mexican government mandates that high quality feeds are used and that monitoring to prevent overfeeding should occur (SEMARNAT 2014b). Producers also monitor feeding to avoid overfeeding (Baja Seas Aquaculture 2018) (Omega Azul 2018).

Area-based and Cumulative Impacts Management

In a desire to work towards area-based management, Mexico introduced the General Law for Sustainable Fisheries and Aquaculture (LGPAS) in 2007, directing aquaculture management planning to consider a more ecosystem-based management approach—including regarding spatial planning and waterbody carrying capacities. The LPGAS requires the development of aquaculture management units (UMA) and aquaculture territorial management plans (POA). Under UMAs, aquaculture development plans are required for geographic "meso-regions" with similar environmental characteristics, aquaculture techniques, and culture species (FAO 2009). For larger areas, POAs must be aligned with the National Ecological Territorial Management Plan and the State Ecological Territorial Management Plan (Saborio Coze and Flores Nava 2009). Both UMAs and POAs influence the decisions regarding the approval of an aquaculture license.

Review of two EIAs associated with this industry suggests that the focus on managing environmental impacts is more site-specific than on system-wide, cumulative impacts—at least for this industry. Some producers have suggested that regulation of marine fish aquaculture in Mexico—relatively new to the country—has limitations (Baja Seas Aquaculture 2018) (Anonymous, pers. comm. 2019b) and have expressed concerns that Mexico may not be adequately considering cumulative impacts of multiple aquaculture operations within an embayment (Anonymous, pers. comm. 2019b), particularly if there is to be substantial growth in the industry.

Regarding management according to potential cumulative, system-wide impacts, adequate information on which to base decision-making is currently lacking. A consortium of researchers including the Mexican government currently has a proposal developed to study the effects of fish farm effluent on the surrounding environment—including by modelling both farm-level and bay-level effects—and to understand carrying capacity to advise aquaculture planning and regulation (Anonymous 2019b). Though this effort is laudable, it is also suggestive that the science to inform carrying-capacity-based management is not yet developed.

Conclusions and Final Score

In summary, there is evidence that Mexican yellowtail production uses the modern operating conditions described in Price et al. (2015) and others to minimize impacts of effluents. Studies of potential impacts from yellowtail farm effluent in other regions have not demonstrated significant impacts and have concluded that effluent impacts can be minimized by strategic farm siting and operation protocols. Data provided by Mexican operators, though temporally limited, show no evidence that effluent discharge is causing or contributing to cumulative impacts at waterbody or regional scales, nor beyond the immediate vicinity of the farm. The current scale of the industry may make it unlikely to contribute to significant waterbody-scale impacts, and data provided by this industry provides snapshots suggesting that effluent impacts from Mexican farms are likely minimal—though limitations in this data are apparent and an area-based management approach that focuses on cumulative impacts is still in development, leaving some uncertainty. Criterion 2 – Effluent scores 7 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		8
F3.2a Content of habitat regulations	3	
F3.2b Enforcement of habitat regulations	3	
F3.2 Regulatory or management effectiveness score		4
C3 Habitat Final Score (0-10)		**6.53**
Critical?	NO	**YELLOW**

Brief Summary

Seabed monitoring of Mexican sites has thus far not indicated measurable benthic impacts, though the specific data provided for this assessment are limited. Studies of yellowtail production internationally (except for Japan) have suggested minimal benthic impacts when properly sited and managed, and Mexican siting and management is consistent with such guidelines. This assessment concludes that Mexican yellowtail farming has minor impacts to the benthic environment that are not leading to significant loss in habitat functionality. Factor 3.1 scores 8 out of 10. Mexico's habitat management approach contains some area-based and ecosystem functionality considerations, though how cumulative impacts are considered and whether future expansion is addressed accordingly is questionable. The score for Factor 3.2a is 3 out of 5. The Mexican industry has provided some evidence (monitoring data and reports) that suggest enforcement and compliance with regulations; enforcement organizations are identifiable and contactable and appear to be active in enforcing some aquaculture regulations, but may have some limitations that reduce effectiveness. The score for Factor 3.2b is 3 out of 5. The final score for Criterion 3 – Habitat is 6.53 out of 10.

Justification of Rating

Factor 3.1 considers the impacts within the immediate vicinity of the farm by evaluating any habitat conversion or loss of ecosystem services as a result of farm construction or operation.

Factor 3.1. Habitat conversion and function

The Gulf of California is one of the most important fishery regions of the eastern tropical Pacific and supports the most productive fisheries in Mexico (Erisman et al. 2010). Similarly, the Bahia

Magdalena, a lagoon complex on Baja California Sur's Pacific side is also highly productive, biologically diverse, and supports one of the state's most important fishing ports (Bizzarro 2008).

Yellowtail production occurs in open-ocean net pens, with Mexico yellowtail farm lease areas ranging from 79 to 300 ha and located <1 to 4 miles offshore (T. Morris, pers. comm. 2019) (Aquaculture North America 2014). The region of the Bahia de Magdalena where one producer operates is characterized as deepwater (>30m) (Bizzarro 2008); producers in Bahia de La Paz state that their net pens are over water exceeding 60 m (N. Sims, pers. comm. 2019), up to 82 m (The Kampachi Company 2018).

Production of farmed fish in open net pens has potential to impact benthic habitats by deposition of solid wastes and resultant biochemical consequences. An EIA for a Mexican yellowtail farm in Bahia de Magdalena suggested that the primary environmental concerns associated with the farm would relate to habitat impacts from uneaten feed and fish waste. In Japan for example (in areas with poor flushing), net pen production of yellowtail has resulted in organic enrichment of the benthos, hypoxia of bottom water, and the increased occurrence of sulfides. Biologically, a shift from a mollusk-dominated community to one dominated by detritivores (polychaetes) and characterized by decreased macrofaunal biomass has been observed; so too has defaunation of the benthos entirely. Recovery of the benthos in this study was described as slow—2 to 5 years following removal of cages in one case (Abo et al. 2013). Significant impacts have also been observed in other studies of *S. quinqueradiata* in Japan, such as Srithongouthai and Tada (2017).

Impacts, however, are likely to be site-specific (Tanner et al. 2007). Though significant impacts have been found in association with Japanese production of *S. quinqueradiata*, sites in Japan are often sited in enclosed basins (Abo et al. 2013) such as inland seas (Srithongouthai and Tada 2017). Studies of other yellowtail production sites, such as in open water or other high current velocity environments, have concluded minimal impact to benthic environments. Multi-year benthic monitoring of similar yellowtail production systems in Hawaii, for example, concludes that yellowtail net pens are not driving changes in sediment composition, redox potential, organic carbon, or species diversity (see Criterion 2 – Effluent, also). Authors conclude that the hydrology of these open-ocean net pen sites (current velocities, depth) is likely effective at dispersing aquaculture waste products; these Hawaii assessments, however, do not report on whether net pen sites and control sites differ statistically, making definitive conclusions difficult (Blue Ocean Mariculture 2013) (Sims 2013) (Plan B Consulting 2015).

As described in Criterion 2 – Effluent, studies of *S. lalandi* farm sites in Australia have concluded minimal impacts to the benthic environmental beneath farms, but likely transport away from farms due to the dissolved nature and low settling velocity of much of the waste (see also Tanner et al. 2007). Later work by Tanner and Fernandes (2010), found elevated levels of ammonia next to cages, but no evidence of increase in phytoplankton abundance, chl-a, seagrass epiphyte biomass, change in seagrass nutrient composition, or changes to infaunal taxon richness or abundance in close proximity to cages. The authors suggest that soluble nitrogen waste (ammonia) is likely rapidly dispersed before being utilized. In the benthic environment, this study found elevated levels of organic carbon and nitrogen content and porewater phosphorus but suggested that overall organic enrichment is "very low." Also, this paper reviews similar studies that found no differences in demersal fish assemblages between sites adjacent to cages and controls (Tanner and Fernandes 2010). Tanner et al (2007) conclude that high rates of nitrogen loss as soluble waste and low settling velocity of yellowtail feces would lead to minimal impacts to the benthic environment.

These findings align with conclusions of EIAs associated with two Mexican farms (BioPesca 2008) (SEMARNAT 2012), and with preliminary observations in Mexico, where producers are required to monitor for benthic habitat impacts. One producer provided copies of results and reports from a 2018–2019 monitoring timeseries: in bimonthly monitoring of sediments and benthic communities in 2018–2019 at "Farm A," results are not suggestive of significant differences between samples collected beneath and down-current of farm sites and references sites (Anonymous 2019b) (T. Morris, pers. comm. 2019). For example, community diversity (H'), evenness (J'; Figure 6), and species richness were comparable between the farm site (as well as a site down-current of the farm) and a reference site (though statistical significance was not reported on and production at this farm had just started in June of 2018). Additionally, levels of sulfides and organic carbon have been below the detection limit of analytical methods in the same 2018–2019 sampling (Anonymous 2019b). A second producer ("Farm B") provided the results from parts of 2017–2019, also suggesting similarities in monitoring data between farm and a reference area—though with data gaps in parts of the year and imprecise alignment of sampling dates between the farm and the reference area (T. Morris, pers. comm. 2019); this data further demonstrates that some monitoring is occurring, though these limitations leave some uncertainty (see also Criterion 2 – Effluent).

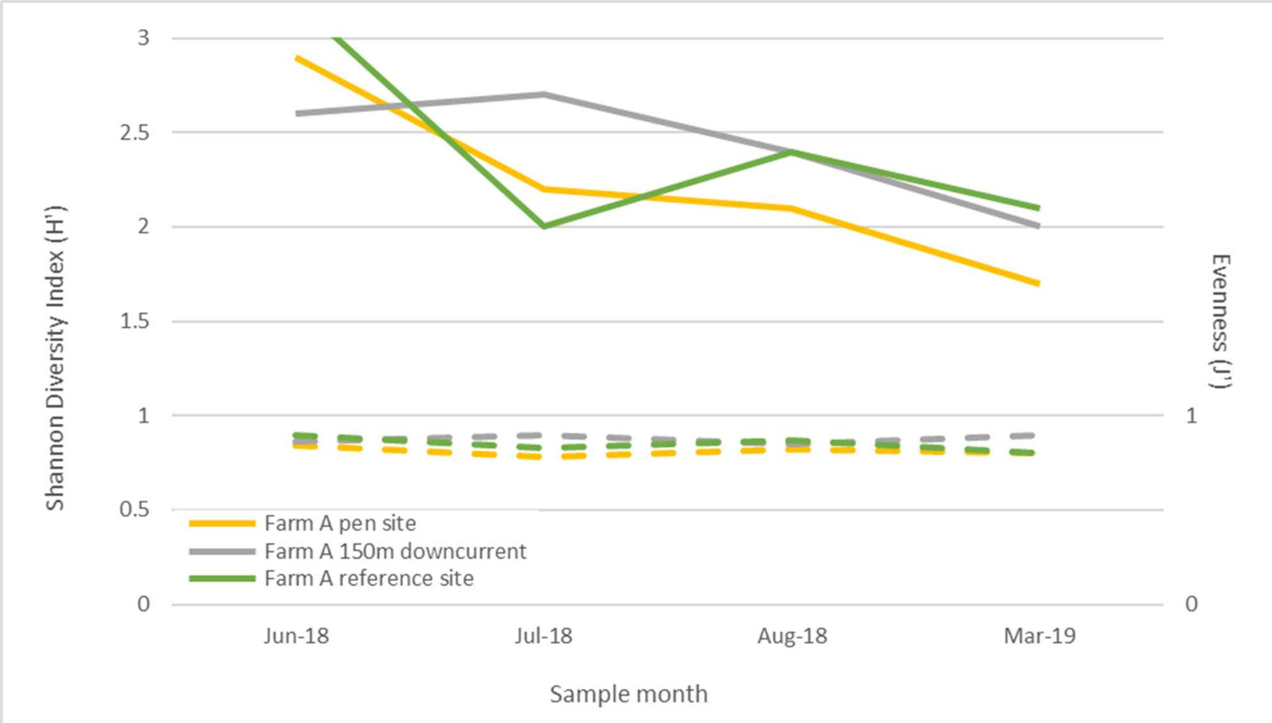

Figure 6. Results of benthic infaunal community monitoring at a Mexican yellowtail farm, 2018–19. Dashed lines refer to species evenness (J'). Industry-provided data. Data: (Anonymous 2019b).

Mexican producers state that there have been no measurable impacts associated with current production thus far (T. Morris pers. comm. 2019), and the limited data provided by two producers for this assessment supports this—though it must be emphasized that definitive statements based on part of one year's worth of sampling data, from one (and only operative since June 2018) farm, with gaps in the time series provided the second farm, and without reporting of statistical conclusions, are tenuous. CIBNOR provided confirmation that at least for one farm no measurable impacts to sediment or water quality have been observed thus far (H. Villarreal, pers. comm. 2019). Attempts to reach SEMARNAT for additional verification and information were unsuccessful. This criterion would benefit from the provision of additional years' worth of sampling data, from multiple producers and confirmation representative of the industry overall. Still, this information provides a useful snapshot that is supported by research on yellowtail and other similarly designed net pen farms elsewhere.

As demonstrated in Japan, waste associated with aquaculture production of *Seriola* species can result in impacts to benthic habitat. The data provided for this assessment does not describe significant differences in metrics measured between farm (including H', J' and richness), downstream, and reference sites, though this data has limitations. However, several studies of yellowtail aquaculture elsewhere—including of a similar production system in Hawaii, and at a site in Australia using higher stocking densities and reported FCR values than those associated with Mexican production—have concluded that yellowtail production has minimal benthic impacts, attributed to appropriate siting considerations and production practices similar to those used in Mexico (Tanner et al. 2007) (Chavez Garcia 2016) (Omega Azul 2018). Similar conclusions have also been drawn for production of other pelagic species in similar production systems (e.g., Welch et al. 2019). Though use of other regions and species as proxies is imperfect and specific data provided for this industry is limited, this assessment concludes that Mexican yellowtail farming has likely minimal impacts to the benthic environment, which are not leading to significant loss in habitat functionality, but scores impacts as “minor–moderate” due to uncertainty associated with those limitations. The score for Factor 3.1 is 8 out of 10.

Factor 3.2. Farm siting regulation and management

<u>Factor 3.2a: Content of habitat management measures</u>
<u>Regulatory infrastructure</u>
Sosa-Villalobos et al (2016) outline the regulatory framework for Mexican aquaculture:

> The development of aquaculture in Mexico is framed in the General Law of Sustainable Fisheries and Aquaculture, which sets out the principles to order, promote, and regulate the integrated management and sustainable use of this productive activity. Additionally, the activity is subject to other federal regulations contained in the General Law of Ecological Balance and Environmental Protection, National Water Law, Regulations of National Water Act, and the Federal Law of Rights. They establish the obligation to have an environmental impact assessment prior to the implementation of the project, granting water use, and water treatment works prior to the discharge of water in order to prevent contamination of receiving water bodies (Velasco et al. 2012).

Additionally, the 1996 LGEEPA (General Law of Ecological Balance and Environmental Protection) established a requirement that an Environmental Impact Assessment be generated for a range of project activities—including aquaculture—that could threaten the preservation of one or more species or cause harm to the ecosystem (SEMARNAT 2002). The assessment process includes an evaluation of possible impacts to surrounding habitat from farm development and operation, and consideration of synergistic and cumulative effects within the relevant ecological system. After initial review of the EIA documentation, SEMARNAT can require an Environmental Impact Statement (EIS) (FAO 2016). For projects under 500 ha (such as yellowtail farms), a site-specific EIA is required, whereas for projects >500 ha, a “regional” EIA is required that lends more attention to cumulative or larger-scale impacts (BioPesca 2008) (FAO 2009).

Environmental impact assessments (EIA) are publicly available through SEMARNAT, and two were reviewed for this assessment. Assessments must describe how projects will comply with Mexican laws and regulations and also consider alternatives and measures to prevent environmental impact according to the best available science (SEMARNAT 2012).

In Mexico, aquaculture falls within the regulatory framework of two departments at the ministerial level, the Department of Agriculture (SAGARPA), and the Department of Natural Resources and Environment (SEMARNAT). Under SAGARPA, there are three agencies most concerned with aquaculture:

1. The National Commission of Aquaculture and Fisheries (CONAPESCA) deals primarily with operating permits.
2. The National Service of Alimentary Health, Quality and Innocuity (SENASICA) oversees animal health.
3. The National Fisheries Institute (INAPESCA) provides research and technical opinions.

Under Environment (SEMARNAT) there are four agencies involved:

1. The Directorate of Environmental Impact, which reviews environmental impact statements, sets operating restrictions and evaluates environmental permits.
2. The National Water Commission (CNA) regulates water use and discharges.
3. The Directorate of Federal Zoning, which regulates uses of the Federal Coastal Zone.
4. The Environmental Protection Attorney's Office (PROFEPA), which enforces environmental regulations.

Siting and area-based management

As discussed in Criterion 2 – Effluent, Mexico has introduced an initiative to work towards area-based management via the General Law for Sustainable Fisheries and Aquaculture (LGPAS) in 2007 and potential habitat (and effluent) impacts are assessed via an Environmental Impact Assessment process and managed through conditions of license. Conditions of license utilize siting considerations such as large tenure sizes, prevailing currents, depth, benthic substrate characteristics, farm spacing, net pen orientation, maximum stocking densities, mandating use of high quality and appropriate volumes of feed, and avoiding siting farms on high-value habitat such as nursery areas and wildlife corridors. Some producers may also move their net pen installations every two years to allow previously-utilized footprints to fallow (Aquaculture North America 2014) (Omega Azul 2018), a technique also used for parasite management elsewhere (Kolkovski and Sakakura 2004).

Mexican conditions of permit require regular monitoring for impacts to the benthos and several provided recent monitoring reports for this assessment. For example, Mexican farms are required to sample for benthic impacts regularly—including for total organic carbon (TOC), sulfides, nitrates, nitrites, and for ecological metrics—including diversity, richness, and evenness (Anonymous 2019b) (T. Morris, pers. comm. 2019). Analysis of benthic samples is conducted by a certified laboratory and results are submitted to SEMARNAT (Figure 6) (SEMARNAT 2018). Monitoring results are intended to inform whether floating aquaculture operations are having impacts to ecological conditions and functioning around and beneath the installations. It is unclear whether any corrective actions (such as adjusting the location, orientation, and spacing of net pen installations) have been taken in response to monitoring results (or whether there has been any need to), but at least one company states that there has not been a need for such actions due to no observations of significant impacts to date (J. Morris, pers. comm. 2019) and a third-party individual familiar with the industry stated that cages are located and managed to effectively minimize impacts (H. Villarreal, pers. comm.

2019). At least one company is also monitoring zooplankton communities surrounding their operations (Anonymous 2019b), and plans to monitor nekton communities are in development (The Kampachi Company 2018).

Despite efforts to develop an area-based management approach that considers cumulative impacts, information adequate to advise such decisions is currently lacking (though in development). Review of two EIAs associated with this industry is suggestive that focus in managing environmental impacts is more site-specific than on system-wide, cumulative impacts—and this has also been a complaint described by members of the industry itself (Anonymous, pers. comm. 2019b), which also acknowledges that as marine finfish aquaculture is new for Mexico, current regulation has limitations (Baja Seas Aquaculture 2018) (see Criterion 2 – Effluent for more detail and references).

In the recent past, Mexico's aquaculture regulation has been criticized for often putting social or political criteria over environmental emphasis in aquaculture planning (FAO 2009). The Mexican government has promoted aquaculture development actively (Aguilar-Manjarrez et al. 2017) and the pace of growth has often exceeded government capacity to regulate for environmental protections (FAO 2009). More recently, the effectiveness of the Mexican EIA process has been similarly questioned (Perevochtchikova and André 2013) (Mellink and Riojas-López 2017) as well as the specific geographical usefulness of environmental norms (FAO 2009).

Monitoring for potential benthic impacts, as required by conditions of license, are occurring with this industry. Both the EIAs and conditions of license examined for this assessment, however, lacked obvious benchmarks (or indicators) that would trigger a response to monitoring results; this has also been pointed out by the literature (Perevochtchikova and André 2013).

Despite some limitations and past critique, Mexico has invested in updating its aquaculture laws and regulations since at least the 2007 *General Law of Sustainable Fisheries and Aquaculture,* and the existing management approach does appear to contain some area-based and ecosystem functionality considerations. Mexico's regulation is set according to ecological principles, such as through conditioning permits according to environmental impact assessments. The existing system still leaves some questions as to how cumulative impacts are considered and whether future expansion is addressed accordingly. The score for Factor 3.2a is 3 out of 5.

<u>Factor 3.2b: Enforcement of habitat management measures</u>

Agencies that regulate and enforce aquaculture in Mexico are apparent, including PROFEPA, SEMARNAT, and CONAPESCA. Agencies are identifiable and contactable (though did not respond to inquiries related to this assessment), and some enforcement information is available via government websites—but with limitations. PROFEPA, which conducts enforcement of environmental regulations, for example, provides access to coarse annual activity data by state and annual reports with more specifics on its activity, although hyperlinks to resources are often broken. CONAPESCA provides up-to-date, downloadable information on annual enforcement activity, though it is coarse, not providing much detail. For example, the agency lists having conducted 60 aquatic site inspection actions in Baja California Sur annually from 2009 to 2018 but does not provide additional information sufficient to understand how many of these interacted with aquaculture operations, nor the results of the work (CONAPESCA, pers. comm. 2019). Neither PROFEPA nor CONAPESCA responded to inquiries for more information for this assessment.

Environmental impact assessments, and subsequent conditions of license, set out requirements for approved producers to abide by, in addition to aquaculture laws and regulations. Prior to beginning aquaculture activities, operators must receive an on-site validation of monitoring programs by PROFEPA (FAO 2009) (SEMARNAT 2014b). Producers are required to submit monitoring reports to 9 different Mexican agencies, including PROFEPA, SEMARNAT, CONAPESCA, INAPESCA, SAGARPA, and the Mexican Navy (T. Morris, pers. comm. 2019); SEMARNAT is charge with scrutinizing monitoring results, while PROFEPA conducts random audits of aquaculture operators (FAO 2009).

Violations of license conditions or Mexican regulations may result in suspension of operations and compensation, as warranted (SEMARNAT 2014b). Corrective actions may also include adjusting siting and spacing of net pens in response to observed impacts in environmental conditions (SEMARNAT 2014b).

The scientific literature describes shortcomings in enforcement of regulations related to aquaculture In Mexico, including in the realms of estuarine habitat protection (Berlanga-Robles et al. 2011), shrimp farm effluent management (DeWalt et al. 2002) (Barraza-Guardado et al. 2013, 2014) (Lebel et al. 2016), tilapia farm effluent management (Sosa-Villalobos et al. 2016), and fishmeal processing (Sosa-Villalobos et al. 2016) (Osuna-Ramirez et al. 2017). Though somewhat dated, Perevochtchikova and Andre (2013) and FAO (2009) describe a lack of follow-up in enforcement actions to regulatory requirements owing to lack of trained staff and resources (Perevochtchikova and André 2013). The FAO (2009) describes a “high-tolerance of non-compliance” by regulatory mechanisms.

There is evidence, however, that Mexico has improved its oversight of the aquaculture sector recently; for example, enforcement of regulations aimed at protecting habitat exists and these institutions are identifiable and contactable. There is evidence that watchdog organizations are using a complaint-driven enforcement process, and that at least some enforcement response has occurred. PROFEPA, the federal institution charged with enforcing environmental regulations has been highly active in implementing a new program targeting aquaculture regulatory enforcement, with evidence of penalties—though not specific to yellowtail farming.

Related to aquaculture, for example, the 2017 annual PROFEPA report indicates that the agency was active in inspecting farms within Mexico’s large shrimp aquaculture industry as part of a new effort seeking implementation of the National Program for Compliance with Environmental Regulations in the Aquaculture Sector. Initiated in 2015, the program has a goal of a 100% inspection rate of aquaculture facilities and has inspected 235 farms (or 57% of those in

Sinaloa) in 2017. Resulting from this work was the enforcement of 235 administrative procedures, of which 90% were resolved with fines and corrective measures. An additional 5 farm inspections initiated from citizen complaints and resulted in additional enforcement actions, including closure of farms (PROFEPA 2017). An additional 153 farms were inspected in 2016, with enforcement actions including fines, corrective actions, and farm closure of both existing and in-construction farms due to lack of federal environmental authorizations (PROFEPA 2016). The program aims to improve upon the very low rate of compliance with environmental impact permitting requirements in its shrimp industry and will enforce regulations concerning land use authorization and discharge of effluents (PROFEPA 2015). This example suggests that compliance with regulations in the aquaculture sector has generally been weak, but that Mexican authorities are investing in improvement and are capable of executing significant enforcement efforts.

Specific to yellowtail, the first farm in Mexico appears to be in compliance with environmental impact permit requirements (Baja Seas Aquaculture 2018); Mexico's other two producers of yellowtail also state that they meet all government requirements (Omega Azul 2018) (King Kampachi 2019). Industry provided copies of sediment and water quality monitoring data and reports submitted to regulators from 2017 to 2019, suggesting compliance with conditions of license aimed at limiting potential impacts from effluent and to underlying habitat. CIBNOR provided confirmation that at least one farm is in compliance with environmental requirements and conditions of license (H. Villarreal, CIBNOR, pers. comm. 2019). This criterion would benefit from additional verification of compliance by regulators to better represent the industry at large; at the time of this assessment, attempts to contact CONAPESCA, SAGARPA, and SEMARNAT) have been unsuccessful.

In summary, enforcement organizations are identifiable and contactable, appear to be active in enforcing effluent-related aquaculture regulations, but may have some limitations that reduce effectiveness. Monitoring data has been provided, suggesting compliance with conditions of license, but with some gaps. The score for Factor 3.2b is 3 out of 5. When combined with the Factor 3.2a score of 3 out of 5, the final Factor 3.2 score is 3.6 out of 10.

Conclusions and Final Score

Studies of yellowtail production internationally (except for Japan) have suggested minimal associated benthic impacts when properly sited and managed; Mexican farm siting and management is consistent with such siting and management guidelines. Monitoring of Mexican sites has thus far not indicated measurable benthic impacts associated with current yellowtail production, though the data provided for this assessment is limited. This assessment concludes that Mexican yellowtail farming likely has minimal impacts to the benthic environment, which are not leading to significant loss in habitat functionality. Mexico's habitat management approach contains some area-based and ecosystem functionality considerations. Mexico's regulation is set according to ecological principles, such as through conditioning permits according to environmental impact assessments, though how cumulative impacts are considered and whether future expansion is addressed accordingly is questionable. The Mexican industry has provided some evidence (monitoring data and reports) that suggest compliance with regulation. Enforcement organizations are identifiable and contactable and appear to be active in enforcing some aquaculture regulations but may have some limitations that reduce effectiveness. Factors 3.1 and 3.2 combine to give a final score of 6.53 out of 10 for Criterion 3 – Habitat.

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)	**6**	
Critical?	NO	**YELLOW**

Brief Summary

Mexican yellowtail production has an apparently low need for antibiotics: all three producers state that they either use no antibiotics or have not yet had a need to. Florfenicol may be maintained on-hand for occasional treatment of *Streptococcus* infections in stressed juvenile fish following out-planting to net pens but has not yet been used. The apparent low need for antibiotics is evident in yellowtail production elsewhere, but the data are challenging to verify. Mexican yellowtail production makes regular use of parasiticides, including Praziquantel (to manage internal parasites in incoming broodstock and occasionally to control skin flukes in fingerlings recently transferred to offshore sites), and hydrogen peroxide (for treatment of external skin fluke parasites at net pen sites). Praziquantel is used infrequently and its use is not considered a risk to human or environmental health. Since hydrogen peroxide quickly dissociates upon contact with seawater, it is also considered a low environmental risk. The regular use of these pesticides is a low-moderate concern and the final score for Criterion 4 – Chemical Use is 6 out of 10.

Justification of Rating

Farmed yellowtail are at risk of infection by parasites and pathogens, and disease has been described as a major bottleneck for industry growth globally (Sicuro and Luzzana 2016). External parasites are the most commonly described issue for *Seriola* species (Kolkovski and Sakakura 2004) (Sims 2013) (INAPESCA 2018a).

The most common health issues for farmed yellowtail in Mexico are ectoparasites *Neobenedenia* and *Heteraxine*, skin flukes that attack the skin and gills, respectively; skin flukes in Mexico are an issue during periods of high temperature—spring through fall (King Kampachi 2019).

Bacterial issues can also be problematic, including *Vibriosis, Pseudotuberculosis*, and *Streptococcis,* often linked to skin abrasions, low salinity events, and high seawater temperatures, respectively. For bacterial infections, antibiotics have historically been recommended as effective response treatments (Aviles-Quevedo and Castello-Orvay 2004).

Antibiotics

Antibiotics, such as Florfenicol, have been used in yellowtail farming, including in Japan and Hawaii (Sims 2013). Mexico does approve some antibiotics for use in fish aquaculture, Table 2, (E. Salazar Sandoval, SENASICA pers. comm. 2019) including some listed as "Highly Important" and "Critically Important" to human health by the World Health Organization (WHO) (WHO 2018). In assessing conditions of license for yellowtail aquaculture, SEMARNAT describes conditions on the use of antibiotics, such prohibition on prophylactic use and that application must follow specification on the label (SEMARNAT 2014b). The use of antibiotics must be reported to and approved by SENASICA (T. Morris, pers. comm. 2019), and SEMARNAT directs producers to mitigate the need for antibiotics by maintaining high fish health standards and best practices (SEMARNAT 2014b).

Table 2. Chemicals approved for us in Mexican fish farming

Class Name	Substance Name	Application
Amphenicols	Florfenicol*	Antibiotic (Bacteria)
	Ethylenediamine dihydroiodide	Parasiticide
Fluoroquinolones	Enrofloxacin**	Antibiotic (Bacteria)
Fosfomycin	Fosfomycin**	Antibiotic (Bacteria)
Tetracyclines	Oxytetracycline*	Antibiotic (Bacteria)

*Listed as Highly Important to human health by WHO (2018); ** listed as "Critically Important" to human health by WHO (2018).

As for the actual use of antibiotics, Mexican yellowtail producers may maintain approved antibiotics on-hand in case of emergency and one producer describes the potential to use Florfenicol on occasion to treat juvenile fish afflicted with *Streptococcus iniae* following the stress of being moved from nursery to net pen, as needed. Such treatments last 12 days (The Kampachi Company 2018) and though dosage was not reported, one producer purchased 5 kg of Florfenicol in 2018 (Anonymous 2019b). All three Mexican producers, however, state that they do not use, or have not used antibiotics in their production and are marketing their product as antibiotic-free (Catalina Offshore Products 2017). Using antibiotics would be detrimental to product marketability and so is not desirable (T. Morris, pers. comm. 2019). No independent data are available with which to verify antibiotic use, though third-party experts interviewed for this assessment have stated that industry claims are accurate (F. Rotman, pers. comm. 2019) or otherwise corroborated low need for antibiotics in North American production of yellowtail (Kevin Stuart, Hubbs-SeaWorld Research Institute, pers. comm. 2019).

Pesticides and Parasiticides

Producers may use praziquantel and chlorine dioxide to treat internal parasites in broodstock (Anonymous 2019b) (Marchiori et al. 2017). Incoming broodstock are de-wormed by a once daily treatment, for 5 days, orally with praziquantel (T. Morris, pers. comm. 2019) and it may be used on younger fish about once every two cohorts (Anonymous 2019b). One producer provided copies of sales records, showing purchase of 45 kg of praziquantel in 2018. Although used in hatcheries and therefore uncertain discharge to the environment, according to Bader (2017) and references therein, the main concern of environmental praziquantel contamination is unintentional killing of free-living non-parasitic flatworms. Free-living flatworms have also shown to indirectly influence macro- and meiofauna (Majdi et al. 2013), potentially changing foodwebs if removed; however, Bader (2017) concludes that even though orally treated fish can excrete active praziquantel, it is unclear if concentrations relevant to environmental disturbance are produced and there is no evidence that high concentrations of praziquantel are being discharged into the environment after a treatment regimen.

For ectoparasites such as skin flukes (e.g., *Neobenedenia spp.)* and gill flukes (e.g., *Heteraxine spp.)*, a freshwater bath is an effective response treatment (some Mexican producers use freshwater baths for small numbers of fish (Anonymous 2019b). Additionally, hydrogen peroxide (H_2O_2) may be used to manage ectoparasites (T. Morri,s pers. comm. 2019) (N. Sims, pers. comm. 2019). Application is dictated by need, as determined by regular parasite monitoring (Anonymous 2019b). Hydrogen peroxide treatments may be applied about 6 times annually during growout (N. Sims, pers. comm. 2019) and are also used to disinfect incoming broodstock—about 3 treatments in 12 days (T. Morris, pers. comm. 2019). One producer provided copies of sales records for purchases of hydrogen peroxide, which totaled 13 MT in the second half of 2018 (Anonymous 2019b), suggesting regular reliance on its use (this producer had only been in production for 6 months in 2018). If all three producers use hydrogen peroxide similarly, this amounts to approximately 78 MT per year.

Upon discharge to open water, hydrogen peroxide is shown to degrade rapidly (Schmidt et al. 2006) by dissociating into environmentally benign hydrogen and oxygen (Lillicrap et al. 2015). The toxicity of hydrogen peroxide is concentration-dependent, with other vertebrates and mammals being much more tolerant than fish (Schmidt et al. 2006). The growth of some bacteria may be adversely affected by hydrogen peroxide, but this is mitigated by the relatively short exposure times due to rapid dilution and decay and the ability of microorganisms to rapidly rebound and repopulate (Schmidt et al. 2006). For these reasons, no long-term effects on populations or communities of microorganisms are expected to result from the use of hydrogen peroxide in aquaculture (Schmidt et al. 2006), though it is worth noting that observations of developed resistance to H_2O_2 in fish ectoparasites have been noted in other (much larger) aquaculture settings, such as farmed salmon in Norway (Seafood Watch 2017b). This assessment considers the use of H_2O_2 by the Mexican yellowtail industry to be of low environmental risk.

<u>Other Chemicals</u>
Producers state that their nets contain no antifouling chemicals (Baja Seas Aquaculture 2018) (Omega Azul 2018), other than copper-alloy net construction (Sims and Vollbrecht 2019).

Conclusions and Final Score

Mexican yellowtail production has an apparently low need for antibiotics: all three producers state that they either use no antibiotics or have not yet had a need to. Florfenicol may be maintained on-hand for occasional treatment of *Streptococcus* infections in stressed juvenile fish following out-planting to net pens but has not yet been used. The apparent low need for antibiotics is evident in yellowtail production elsewhere, but the data are challenging to verify. Mexican yellowtail production makes regular use of parasiticides, including Praziquantel to manage internal parasites in incoming broodstock, and hydrogen peroxide for treatment of external parasites (skin flukes) at net pen sites. Praziquantel is used infrequently during broodstock cycling, and on juveniles in the hatchery or recently transferred offshore, and its use is not considered a risk to human or environmental health. As hydrogen peroxide quickly dissociates upon contact with seawater, it is also considered a low environmental risk. The regular use of these pesticides is a low-moderate concern and the final score for Criterion 4 – Chemical Use is 6 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

Feed parameters	Value	Score
F5.1a Feed Fish Efficiency Ratio (FFER)	1.48	6.31
F5.1b Source fishery sustainability score	-2.00	
F5.1: Wild fish use score		5.72
F5.2a Protein IN (kg/100kg fish harvested)	61.20	
F5.2b Protein OUT (kg/100kg fish harvested)	23.86	
F5.2: Net Protein Gain or Loss (%)	-46.68	5
F5.3: Feed Footprint (hectares)	17.63	4
C5 Feed Final Score (0-10)		**5.11**
Critical?	NO	**YELLOW**

Brief Summary

Mexican yellowtail feeds use fishmeal (36.7% inclusion) and fish oil (12.4% inclusion) as feed ingredients with substantial use of byproduct sources. The Forage Fish Efficiency Ratio (FFER) is 1.48 and the marine ingredients are sourced from sustainable fisheries; the Wild Fish Use score is 5.72 out of 10. The total feed protein content is approximately 45%, increasingly being supplied by crop-based ingredients. There is an estimated 46.7% net loss in edible protein during production and a moderate feed footprint. The final Criterion 5 – Feed score is 5.11 out of 10.

Justification of Rating

Detailed information on feed ingredients was provided by two producers. As the feed information was provided by two out of three total producers representing the majority of total production, this information is assumed to be representative of the industry as a whole. This data is aggregated and reported as anonymous herein, complimented with data reported in the scientific literature and industry websites. EWOS Canada and Skretting are listed as feed providers by all Mexican producers (Astiazaran et al. 2016) (Baja Seas Aquaculture 2018) (N. Sims, pers. comm. 2019) (Omega Azul 2018).

Factor 5.1. Wild fish use

The Mexican yellowtail industry makes use of commercial feeds based on fishmeal and fish oil (both including byproduct sources) and crop-based ingredients (Aquaculture North America 2014) (Catalina Offshore Products 2017) (Kampachi Farms 2018).

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

The Kampachi Company (2018) reports an eFCR of 1.31, which aligns with the low end of the eFCR range achieved in recent experimental feed trials (Benitez-Hernández et al. 2018). Omega Azul (2018) reports an eFCR of 1.4, which aligns with the median found in feeding trials by Chavez Garcia (2016) and a reference diet used by Benitez-Hernandez (2018). This assessment uses an average of 1.36 from these two estimates.

Fishmeal inclusion rates in yellowtail diets are reported to range from 30 to 55% (Drawbridge et al. 2011) (Chavez Garcia 2016) (Fotedar and Suyasa 2016) and content may vary depending on the type of feed used in various stages of growout; manufactured feed used in Mexican yellowtail production ranges from 30 to 45% in fishmeal inclusion rate (Anonymous 2019b) (T. Morris, pers. comm. 2019). Fish oil inclusion in feeds used in Mexican yellowtail production ranges from 11 to 20% (T. Morris, pers. comm. 2019). The weighted average inclusion levels based on data provided by industry (two producers totaling greater than half of total production) for fishmeal and fish oil used in this assessment are 36.7% and 12.4%, respectively (Table 3).

According to industry publications and data provided for this assessment, about 25 to 41% of fishmeal and 25 to 59% of fish oil are sourced from trimmings and other byproducts (The Kampachi Company 2018) (T. Morris, pers. comm. 2019). Weighted averages from specific data provided by two companies were used for byproduct inclusion in fishmeal (37.7%) and fish oil (56.2%).

Table 3. Values used in 5.1a—Feed Fish Efficiency Ratio calculation. Fishmeal, fish oil, and byproduct fractions are based on weighted averages according to the proportion of feed types used through the growout cycle (not including juvenile stage). Data from two producers and one feed company.

Parameter	Data
Fishmeal inclusion level	36.7%
Percentage of fishmeal from byproducts	37.7%
Fishmeal yield (from wild fish)	22.5%
Fish oil inclusion level	12.4%
Percentage of fish oil from byproducts	56.2%
Fish oil yield	5%
Economic Feed Conversion Ratio (eFCR)	1.36
Calculated Values	
Feed Fish Efficiency Ratio (fishmeal)	1.38
Feed Fish Efficiency Ratio (fish oil)	1.48
Seafood Watch FIFO Score (0-10)	**6.31**

Although the use of fishmeal and fish oil in yellowtail feeds is high, dependency on whole-fish sources is reduced by high inclusion rates of byproducts, reducing the FFER to 1.38 for fishmeal and to 1.48 for fish oil. This assessment uses the higher of the two values (fish oil; 1.48), resulting in a score for Factor 5.1a – Feed Fish Efficiency Ratio is 6.31 out of 10.

Factor 5.1b – Sustainability of the source of wild fish

The sources of fishmeal and fish oil vary according to a variety of factors including price, availability, quality, and source fishery adherence to food safety and sustainability certifications. Skretting and EWOS both provided some useful general information on their websites and in annual sustainability reports (Skretting 2016) (Cargill 2017), but information on source fisheries specific to the Mexico yellowtail industry was provided by producers and used for this assessment (Table 4) (T. Morris, pers. comm. 2019).

Table 4. Capture fisheries supplying Mexican yellowtail feeds, as reported by anonymous industry contact
*Report did not differentiate between Eastern and Western Bering Sea Alaska pollock stocks, so both are included here.

<table>
<tr><th>Target</th><th>Stock</th><th>FishSource score</th><th>SW score</th></tr>
<tr><td>Anchoveta</td><td>Southern Peru/Northern Chile</td><td>All >6</td><td>-4</td></tr>
<tr><td>Jack mackerel</td><td>Pacific Southeast Ocean</td><td>All >6, 8 stock health</td><td>-2</td></tr>
<tr><td>Yellowfin sole</td><td>Bering Sea and NE Pacific</td><td>All >6, 8 stock health</td><td>-2</td></tr>
<tr><td>Gulf menhaden</td><td>Gulf of Mexico</td><td>All >6, 8 stock health</td><td>-2</td></tr>
<tr><td>Thread herring</td><td>Pacific Ocean</td><td>All >6</td><td>-4</td></tr>
<tr><td>North Pacific hake</td><td>Pacific Ocean</td><td>All >8</td><td>0</td></tr>
<tr><td rowspan="2">Alaska pollock*</td><td>W Bering Sea</td><td>All >6</td><td>-4</td></tr>
<tr><td>E Bering Sea</td><td>All >8</td><td>0</td></tr>
<tr><td colspan="3">Average</td><td>-2</td></tr>
</table>

Significant efforts have been made to improve sourcing of fishmeal and fish oil; in particular, larger companies such as Skretting have made public commitments through their supplier codes of conduct[5,6] to encourage certification (either through MSC or IFFO) of source fisheries—among other initiatives. Of the 8 fisheries listed as supplying feeds in Table 4, all feature FishSource scores of >6 and of those, 3 score 8 or higher in “Stock Health” and 2 score entirely above 8. Table 4 outlines the corresponding Seafood Watch score assigned to each fishery and for Factor 5.1b of this assessment, an average score of the all source fisheries is used. Thus, the sustainability score is –2 out of –10, and this results in a final score for Factor 5.1b of –0.54 out of –10 which is deducted from the FFER score (6.31 out of 10).

When combined, the Factor 5.1a and Factor 5.1b scores result in a final Factor 5.1 score of 5.72 out of 10.

Factor 5.2. Net protein gain or loss

Specific data on the total protein content of Mexican Yellowtail feeds were provided by two producers, indicating a protein content range of 43 to 47%, aligning closely with values reported in the literature. The mean value of 45% is used in this assessment. This protein is supplied by a variety of feed ingredients considered both edible and non-edible from a human perspective, all of which have an environmental impact from their production.

In addition to protein from marine ingredients, yellowtail feeds are making increasing use of plant-based and other non-marine proteins. For example, investigation into the viability of soy-based proteins to replace fishmeal is ongoing (Baja Seas Aquaculture 2018) (Sims and Vollbrecht 2019) and experimental inclusion levels of at least 10 to 30% have been successful (Buentello et al. 2014). Chavez Garcia (2016) found success with 15% soybean meal inclusion

[5] EWOS Supplier Code of Conduct: http://www.ewos.com/wps/wcm/connect/ewos-content-group/ewos-group/sustainability/code-of-conduct-suppliers
[6] Skretting Supplier Code of Conduct: http://www.skretting.com/en/our-story/sustainability/

(replacing 25% of protein) and there is suggestion that modern yellowtail feeds may reach 30 to 50% soybean protein concentrate inclusion (Benetti et al. 2016) (Kampachi Farms 2018). Similarly, research feeds have found success with inclusion rates of 9% poultry meal and 14% cornmeal (Chavez Garcia 2016). High level of algae product inclusion may also be successful for *S. rivoliana* (Sicuro and Luzzana 2016). Feeds may also use fish processing byproducts, wheat flour, corn gluten meal, pea proteins, canola oil, dried yeast, meat meals, vitamins, minerals and amino acids (Catalina Offshore Products 2017) (Kampachi Farms 2018). At least two producers are not using feeds containing land animal ingredients due to the demands of their markets (the third producer did not provide information on feed ingredients) (Anonymous 2019b) (T. Morris, pers. comm. 2019).

Specific composition of feed used in Mexican yellowtail aquaculture, representing approximately 50% of total production, was provided for this assessment and is aggregated and reported according to broad categories to preserve proprietary information, in Table 5.

Table 5. Protein sources in Mexican yellowtail feeds; source: (Anonymous 2019b) (T. Morris, pers. comm. 2019)

Ingredient	Inclusion rate (%)	% of total feed protein*	Edible?
Crop ingredients	54	45.76%	Yes
Fishmeal	36.7	54.24%	Yes (whole fish)/ No (byproducts)

Regarding harvested protein outputs, farmed yellowtail are approximately 21.2% (Fotedar and Suyasa 2016) to 22.2% protein (Blue Ocean Mariculture 2018); this assessment uses the median of 21.7%. The edible yield of farmed yellowtail is 79% (Aviles-Quevedo and Castello-Orvay 2004). One producer reported the sale of leftover fish scraps/trimmings (i.e., non-edible byproducts) from harvested farmed fish to several local companies for use in pet food and fertilizers (T. Morris, pers. comm. 2019), but Mexican yellowtail production is in its infancy and other producers have not yet developed (but are actively pursuing) such markets (N. Sims, pers. comm. 2019). As such, one of the three companies' further use leads to a 33% assumed use of byproducts from harvested fish.

Table 6. Parameters used in calculating Factor 5.2

Parameter	Data
Protein content of feed	45%
Percentage of total protein from non-edible sources (byproducts, etc.)	21.6%
Percentage of protein from edible sources	78.74%
Economic Feed Conversion Ratio	1.36
Edible Protein INPUT per 100kg of farmed yellowtail	48.69
Protein content of whole harvested yellowtail	21.7%
Edible yield of harvested yellowtail	79%
Percentage of farmed yellowtail byproducts utilized	33%
Utilized Protein OUTPUT per 100kg of farmed yellowtail	25.96
Net protein loss	46.68%
Seafood Watch Score (0-10)	**5**

Protein in feeds used for Mexican farmed yellowtail is sourced from 54.2% marine ingredients (fishmeal made from whole fish and from byproducts) and 45.8% crop ingredients. All the crop-based protein provided is considered to come from sources suitable for human consumption meaning that 78.7% of the total protein is considered to come from edible sources. With consideration of the protein outputs in the harvested yellowtail, and the further use of yellowtail byproducts, there is an overall net edible protein loss of 46.7% (Table 6) leading to a Factor 5.2 score of 5 out of 10.

Factor 5.3. Feed footprint

Mexican yellowtail feeds make use of a mix of marine-based ingredients (fishmeal and fish oil) and crop ingredients. Based on feed formulation data obtained from two industry contacts, three industry websites, and two feed companies, the average area of ocean and land areas required to produce the feed necessary to produce one MT of farmed Mexican yellowtail was estimated (Table 7).

Table 7. Feed footprint equation data

Parameter	Data
Marine ingredients inclusion	49.1%
Crop ingredients inclusion	50.9%
Land animal ingredients inclusion	0%
Ocean area (hectares) used per MT of farmed yellowtail	17.37
Land area (hectares) used per MT of farmed yellowtail	0.26
Total area (hectares)	17.63
Seafood Watch Score (0-10)	**4**

The area necessary for production of marine ingredients required for one MT of Mexican yellowtail is 17.37 ha/MT of farmed fish. The area necessary for production of terrestrial (crop) ingredients required for one MT of Mexican yellowtail is 0.26 ha/MT. The combination of these two values results in an overall feed footprint of 17.63 ha/MT of farmed fish. This results in a final Factor 5.3 score of 4 out of 10.

Conclusions and Final Score

Mexican yellowtail feeds use fishmeal (36.7% inclusion) and fish oil (12.4% inclusion) as feed ingredients with substantial use of byproduct sources. The FFER is 1.48 and the marine ingredients are sourced from sustainable fisheries; the Wild Fish Use score is 5.72 out of 10. The total feed protein content is approximately 45%, increasingly being supplied by crop-based ingredients. There is an estimated 47% net loss in edible protein during production and a moderate feed footprint (Factors 5.2 and 5.3 score 4 out of 10). The final Criterion 5 – Feed score is 5.11 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- Impact: competition, genetic loss, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations
- Sustainability unit: affected ecosystems and/or associated wild populations.
- Principle: 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	3	
F6.1 Final escape risk score		7
F6.2 Competitive and genetic interactions		8
C6 Escape Final Score (0-10)		**7**
Critical?	NO	**GREEN**

Brief Summary

Net pens, as open systems, represent an inherent risk of escape by farmed stock due to operational failures and human error. Mexican producers have reported trickle losses and isolated escape events (up to 1500 fish) but have apparently not experienced a major escape event (defined as >5% of the holding unit stock). Producers minimize escapes using management measures including daily monitoring, use of high-quality construction materials (e.g., copper alloy nets), and installation of net coverings; nevertheless, the reported failures and human errors demonstrate that the risk of escape must be considered moderate and Factor 6.1 Escape Risk scores 4 out of 10. The known escape events have been reported (by the producers) to also have high recapture rates of between 47 to 95% which increases the Escape Risk score to 7 out of 10. Both species of farmed *Seriola* yellowtail cultivated in Mexico are native to the region of production. Hatcheries make use of locally caught broodstock, replacing a portion of total broodstock with new adults annually to refresh the hatchery's gene pool. As such, Mexican farmed yellowtail are native, and likely of high genetic similarity to their wild conspecifics, representing low risk of impact should a large escape occur. Factor 6.2 scores 8 out of 10 and the final score Criterion 6 – Escapes is 7 out of 10.

Justification of Rating

Factor 6.1. Escape risk

Complete containment of cultured fish has been described as nearly impossible (Purcell et al. 2015), and net pens in particular are considered to have a high risk of escapement (Blanchfield et al. 2009; Anderson et al. 2015a). Mexico yellowtail producers use a number of management practices to reduce risk of fish escape, particularly the use of copper alloy nets, routine (daily) inspections of net integrity above and/or below the surface (Baja Seas Aquaculture 2018) (Omega Azul 2018) (T. Morris, pers. comm.). Producers cover cages with nets (19 mm mesh; T. Morris, pers. comm. 2019) to dissuade predators, which also serves to limit escape opportunity. King Kampachi uses similar measures, including copper alloy nets to reduce risk of escapement (King Kampachi 2019) (N. Sims, pers. comm. 2019). Environmental assessment of proposed yellowtail farms have concluded that, due to design and materials used in net pen construction, escape can be effectively minimized (SEMARNAT 2014b).

Despite Best Management Practices aimed at escape prevention, escapes of Mexican farmed yellowtail occur (SEMARNAT 2014b). To date, industry has reported this phenomenon as mostly trickle losses during transport or as isolated events (T. Morris, pers. comm. 2019) (N. Sims pers. comm. 2019). One producer makes escape data publicly available and the most recent report describes two events. One event in 2018 involved 1,500 fish due to a net failure in bad weather. In this instance, most escaped fish reportedly remained within the secondary copper alloy mesh (a second layer of netting). The initial recapture rate was 47% with follow-up efforts reaching an estimated 95% (King Kampachi 2019) (N. Sims, pers. comm. 2019). A second escape of 560 fish was also reported in 2019 due to human error with similar recapture efforts following the event (no recapture rate reported) (King Kampachi 2019).

Escape logs provided for this assessment by the same company indicate at least one additional smaller escape event in 2018—a total of at least three escape events in one year of production. Producers note that recapture by baiting with feed is effective—due to fish fidelity to cages—and that escapees from their farm are also exposed to rapid predation by larger fish that aggregate to the farm structures (King Kampachi 2019) (Sims 2013) (N. Sims, pers. comm. 2019), though predatory fish may not aggregate around Mexican cages to the extent this is observed in Hawaii (The Kampachi Company 2018). Escape data are also apparently reported to Mexican regulators (King Kampachi 2019) and one producer provided both copies of standard reporting forms and escape reports from 2018 (Anonymous 2019b). Attempts to acquire this information or verification from Mexican regulators were not successful for this assessment.

The scientific literature is thin on documentation and details of escapes from *Seriola* farms. Escapes have been reported in Australia (Jensen et al. 2010) and producers of *S. rivoliana* in Hawaii concede that there are at least some escapes that occur due to breaches in netting—but describe it as “leakage,” rather than large escape events. Producers there report recapture rates as 30 to 40% (Seafood Watch 2014), though these industry-provided reports may also be unverified.

Mexican yellowtail farming occurs in an open system (net pens) and may experience occasional trickle losses and larger escape events—apparently less than 5% of holding unit stock, though verification of specifics would provide more certainty. Producers use multiple prevention methods, such as daily monitoring, net pen coverings, and copper alloy net pen construction design in escape prevention, exceeding Best Management Practices recommended by regulators.

Seafood Watch allows for Factor 6.1 to be adjusted to account for the effectiveness of recapture. Recapture of escaped fish associated with Mexican yellowtail aquaculture is apparently effective and reported recapture rates are 47 to 95% for one escape event. Without data from other escape events or regulatory verification, this assessment uses the low end of the range at 47% on a precautionary basis. This factor scores 4 out of 10 for escape risk, with an adjustment of 3 for fish recapture. The score for Factor 6.1 Escape Risk is 7 out of 10.

Factor 6.2. Competitive and genetic interactions
Seriola lalandi is native to the region in which Mexico's aquaculture production of this species occurs. The Gulf of California supports the country's most productive fisheries, including a 338 MT annual harvest of wild *S. lalandi* (Erisman et al. 2010). Investigations into the population structure of *S. lalandi* to date have highlighted differentiation at large biogeographical (e.g., cross-hemispheric) scales. *Seriola lalandi* is actually a cryptic multi-species (clade) complex, with large-scale oceanographic barriers (such as the equatorial ocean) isolating populations of these pelagics (Martinez-Takeshita et al. 2015) (Purcell et al. 2015). *Seriola lalandi* broodstock used in Mexican aquaculture of this species is harvested from the NE Pacific population. Although researchers point to population differentiation of *S. lalandi* at large oceanographic scales, they also caution about potential local adaptation, which is not well understood for this species but increasingly recognized as a reality among broadly-distributed species (Purcell et al. 2015).

Like *S. lalandi*, *S. rivoliana* is widely distributed globally, and is also native to the waters in which it is farmed in the Mexican Pacific (Mansour et al. 2011) (Quiñones-Arreola et al. 2015). This species is also targeted by Mexican fisheries, though catch appears to be aggregated into a "jacks" category and fisheries information appears to otherwise be limited (CONAPESCA 2018). Attempts to contact CONAPESCA for more specific catch information were unsuccessful. Additionally, the literature on population genetics for this species is sparse.

Mexican yellowtail farmers rely on the hatchery-production of juvenile yellowtail for growout—a practice intended to provide more control over supply and eliminate reliance on collection of wild juveniles for farming (as is done in Japan and was once done in Mexico); there are three facilities each producing the two species farmed in Mexico. Although hatchery production represents potential risks to wild stocks in the form of genetic introgression from escaped farm fish (i.e., due to different survival profiles, hatchery populations will have a different genetic profile than wild populations), by using locally sourced broodstock and cycling 20 to 40% of new wild caught broodstock into the hatchery pool annually, this is minimized (Omega Azul 2018) (J. Morris, pers. comm. 2019). It is noted that one farming company (representing about 40% of Mexico's production) appears to be largely reliant on farmed broodstock, with only minimal use of wild-caught broodstock (Baja Seas Aquaculture 2018) (Rotman 2019). The number of generations of domestication is not known; however, considering the young age of the industry in Mexico it is considered small and not yet of a significant concern for the presentation of phenotypic differences.

Using native fish and minimizing domestication selection in the hatchery setting also appears to be a strategy employed elsewhere in yellowtail production (Sims 2013), though selective breeding is being explored by this industry (The Kampachi Company 2018). All Mexican producers promote their use of native yellowtail as well as their hatchery strategies as deliberate management of genetic risk to native populations (Baja Seas Aquaculture 2018) (Omega Azul 2018) (King Kampachi 2019) and environmental assessments of proposed yellowtail production have concluded that escaped farm fish pose low invasive and genetic risk to wild populations (SEMARNAT 2014b).

Escaping farmed yellowtail are also likely to be vulnerable to predation, but no data are available with which to estimate the proportion of escapees or the reduction in the potential impact. Overall, both species of farmed *Seriola* yellowtail cultivated in Mexico are native to their region of production. Hatcheries make use of locally caught broodstock, replacing a portion of broodstocks annually to refresh the hatchery's gene pool. Mexican hatcheries make use of F1 and P1-F1 hybrid fingerlings. As such, Mexican farmed yellowtail are considered to be of high genetic similarity to their wild conspecifics, representing a low risk of impact should they escape. The score for Factor 6.2 is 8 out of 10.

Conclusions and Final Score

Net pens, as open systems, represent an inherent risk of escape by farmed stock due to operational failures and human error. Mexican producers have reported trickle losses and isolated escape events (up to 1500 fish) but have apparently not experienced a major escape event (defined as >5% of the holding unit stock. Producers minimize escapes using management measures including daily monitoring, use of high-quality construction materials, and installation of net coverings; nevertheless, the risk of escape is considered moderate and Factor 6.1 Escape Risk scores 4 out of 10. The few escape events that have been reported have also been associated with high recapture rates of between 47 to 95%, but without third party verification, this assessment assumes the low end of the range and the adjusted Factor 6.1 score is 7 out of 10. Both species of farmed *Seriola* yellowtail cultivated in Mexico are native to the region of production. Hatcheries make use of locally caught broodstock, replacing a portion of total broodstock with new adults annually to refresh the hatchery's gene pool. As such, Mexican farmed yellowtail are native and likely of high genetic similarity to their wild conspecifics, representing low risk of impact should a large escape occur. Factor 6.2 scores 8 out of 10 and the final score Criterion 6 – Escapes is 7 out of 10.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	5	
Critical?	NO	YELLOW

Brief Summary

Since the quality and availability of disease data is moderate (i.e., Criterion 1 score of 5 out of 10 for the disease category), the Seafood Watch risk-based assessment was used. The *Seriola* genus generally has low susceptibility to disease in current culture conditions; however, the small scale of the current industry may be a factor. Like many aquaculture settings, the higher densities of farmed fish present some challenges to fish health; in Mexico, parasite issues (*Neobenedenia* and *Heteraxine* skin and gill flukes) are the primary concern. Net pens are open to the surrounding environment and therefore to the exchange of pathogens and parasites from wild fish to farmed fish and vice versa. High survival rates typical of Mexican yellowtail production correspond with low disease-related mortalities, but parasite numbers are substantial as indicated by average and peak prevalence and the regular use of pesticides. The monitoring of wild fish in Mexico is limited, and while monitoring at a similar farm in Hawaii does not indicate the transmission of parasites from the farm to wild fish, these results cannot confidently be used to assume there is a similar lack of transmission at the sites covered in this assessment in Mexico. As such, there remains a concern regarding the open nature of the production system and the discharge or pathogens and parasites. The final score for Criterion 7 – Disease is 5 out of 10.

Justification of Rating

As the quality and availability of disease data is moderate (i.e., Criterion 1 score of 5 out of 10 for the disease category), the Seafood Watch risk-based assessment was used.

Disease has been described as a major bottleneck for yellowtail industry growth globally (Sicuro and Luzzana 2016), particularly in Japan; for example, bacterial infections occur during the larval stage in yellowtail production (Kolkovski and Sakakura 2004) and have historically caused the most common disease issue (*Enterococcus seriolicida*) in Japanese production of closely related *Seriola dumerili.* The bacterial pathogens *Lactococcus garvieae* and *Nocardia* spp. have posed similar challenges in Japanese production of *Seriola quinqueradiata*. Japan has also been challenged by iridovirus, muscle parasites, and myxosporean parasites, with at least four diseases linked to periodic epidemics and mass mortalities. An ectoparasite, the skin fluke *Benedenia seriolae* is a serious issue for Japanese production as well (Sicuro and Luzzana 2016) (Trasviña-Moreno et al. 2017). Still, typical juvenile mortality rates in Japan are around 2 to 10% (Nakada 2008) and due to the use of vaccines against *L. garvieae*, estimated losses of cultured fish have been halved to about 4 to 5% over the production cycle in Japan more recently (Abo et al. 2013).

In Australia and New Zealand, metazoan parasites such as flatworms are primary challenges during growout, described as a "major threat" to sea cage culture of *S. lalandi* (Sepúlveda and González 2015) (Sicuro and Luzzana 2016). In Chile, too, heavy infections of a highly pathogenic monogenean parasite have affected culture of *S. lalandi*, attributed to transmission from wild to farmed fish (Sepúlveda and González 2015). In Hawaii, farmed *S. rivoliana* can also be affected by a skin fluke (Sims 2013) and parasite issues in *S. lalandi* are reported from California (Sicuro and Luzzana 2016). Rotman (2019) reports some issues with skin flukes and gill flukes, as well as at least 4 other parasites—but which have been described as "not terribly problematic."

<u>Mexican Yellowtail – Parasites</u>

Five parasitic copepods known to affect *Seriola lalandi* are reported in Mexico, including some specific to this host species (Ho et al. 2001) (Morales-Serna et al. 2012), and a diversity of monogenean parasites (external flatworms) affecting teleosts are also native to the Mexican north Pacific (Mendoza-Garfias et al. 2017). Seasonal challenges with the skin fluke (*Neobenedenia* spp.) and gill parasite (*Heteraxine* spp.) issues have been reported in Mexico, and these parasites are commonly found on several species of wild fish (N. Sims, pers. comm. 2019); management of skin fluke infestations represents a significant challenge to offshore production (Trasviña-Moreno et al. 2017) (Sims and Vollbrecht 2019). Monogenean parasites are the most common parasite issue for *Seriola* aquaculture (Vivanco-Aranda et al. 2019) and a substantial portion of the scientific literature on disease of cultured *Seriola* in this region has been dedicated to *Neobenedenia* (and *Benedenia* in other regions). Skin fluke infestations are issues for producers in both Bahia de Magdalena and the Gulf of California (Trasviña-Moreno et al. 2017) (Sims and Vollbrecht 2019) and can lead to secondary infection due to the fish rubbing on netting in an attempt to remove the parasites (Sims and Vollbrecht 2019).

Some information on skin fluke prevalence is available: one producer provided results of skin fluke monitoring for 2018–2019, though without baseline data on local skin fluke abundance (which does not exist), it is difficult to understand prevalence relative to normal rates. Seasonality is evident and observed parasite densities ranged from 0 to 249 per fish, with a mean of 14.6 (Anonymous 2019b).

<u>Mexican Yellowtail – Bacterial Challenges</u>

Additional challenges are associated with bacterial Vibriosis (following abrasions to skin), Pseudotuberculosis (particularly during low salinity events), and *Streptococcus* (during periods of high water temperature and high stress, and treated with Florfenicol) (Aviles-Quevedo and Castello-Orvay 2004) (INAPESCA 2018a) (The Kampachi Company 2018). To date, these are suggested as manageable and not yet having caused major issues (Rotman 2019).

Mortality Rates

Although the current small scale of the yellowtail farming industry in Mexico is partially credited for disease not yet being a major issue (T. Morris, pers. comm. 2019) (N. Sims, pers. comm. 2019), Nakada (2008) suggests *Seriola* spp. generally have a high resilience to disease in cultivation. Overall survival in Mexican production is high, reported as 88 to 95% (Aviles-Quevedo and Castello-Orvay 2004) (INAPESCA 2018a) with no mass mortalities reported (Vivanco-Aranda et al. 2019). Specific disease-related mortalities are reported at less than 5% annually and seasonal, often attributable to poor management during periods of environmental stress, facilitating *Neobenedenia* and *Heteraxine* infections (Anonymous 2019b) (Aviles-Quevedo and Castello-Orvay 2004). Trial production in southern California also reports high survival in the nursery stage (Rotman 2019) and growout in Hawaii has achieved as high as 98% survival (Sims and Vollbrecht 2019).

Transmission to Wild Stocks

Despite the apparently low disease-related mortality, the open nature of yellowtail net pens still presents risk of transmission of the pathogens and parasites between farmed and wild fish. Regarding the species mentioned above, extensive sampling of wild *Seriola* globally has suggested that high infestation rates of *Neobenedenia* is not typically an issue for wild fish (Sepúlveda and González 2019), but the same study also describes the "significant" ability of the *Neobendenia* genus to colonize new hosts, and describes farmed *Seriola* as a likely source of parasite eggs to the surrounding environment. In addition, the transmission of *Benedenia* parasites from farmed to wild Seriola has been demonstrated empirically in Australia (Chambers and Ernst 2005), where wild *S. lalandi* have also been documented in the vicinity of *S. lalandi* aquaculture cages (Hutson 2007). The transmission of other parasite genera from wild to farmed *Seriola* fish has also been demonstrated (Bravo et al. 2017), further indicating the ease of transmission between fish, and the possibility of transmission of a pathogen amplified in a *Seriola* farm to wild fish.

Monitoring for parasites on wild Seriola close to a *S. rivoliana* farm is undertaken in Hawaii, and results (2008 to 2017) give no indication that levels in wild fish are elevated due to transmission from the farm (which, like Mexico, suffers from similar parasites and relies on regular pesticide use to control them (Blue Ocean Mariculture 2014) (Blue Ocean Mariculture, personal communication September 2018). Although these results may reduce the concern regarding parasite transmission in Mexico, due to the different characteristics of the receiving environment in Mexico, they cannot confidently be used to assume there is a similar lack of transmission at the sites covered in this assessment.

Management

In general, research on production of *Seriola* spp. globally has described effective disease mitigation strategies, including deeper cage submersion (one Mexican producer uses submersible cages) and breeding for resistance (currently being explored) (Sicuro and Luzzana 2016) (Sims and Vollbrecht 2019). A Hawaiian farm was able to effectively manage disease and parasite issues with attentive husbandry and occasional use of hydrogen peroxide—with no demonstrated transmission of fish health issues between farmed and wild fish (Seafood Watch 2014). Vaccination has also been effective at managing some diseases, reducing the need for antibiotics in other regions (Sicuro and Luzzana 2016); this is currently being explored for Mexican production (The Kampachi Company 2018).

Prevention of parasitic infections with *Neobenedenia* spp. in open production systems is difficult (Trasviña-Moreno et al. 2017), but parasite densities and the effects of infestation can be managed (N. Sims, pers. comm. 2019). In Mexico, producers move net pens periodically (Kolkovski and Sakakura 2004) (Aquaculture North America 2014), and Mexican guidelines also prescribe low stocking densities, net cleaning, attention to proper nutrition, and close monitoring of fish health (Aviles-Quevedo and Castello-Orvay 2004) (Baja Seas Aquaculture 2018). For issues with ectoparasites like *Neobenedenia* and *Heteraxine*, strategically-timed freshwater baths are an effective treatment (for smaller numbers of fish) (Hutson 2007) (Trasviña-Moreno et al. 2017) (The Kampachi Company 2018), as well as use of hydrogen peroxide, although both approaches present logistical challenges (N. Sims, pers. comm. 2019). Mexican producers nonetheless employ freshwater and hydrogen peroxide baths regularly (see Criterion 4 – Chemical Use), with one producer reporting relying on hydrogen peroxide baths for net pen fish about 6 times/year (Anonymous 2019b). The use of copper-alloy mesh in net pen construction, which reduces substrate for parasite eggs, has been an important tool in managing parasites like *Neobenedenia* (Rotman 2019) (Sims and Vollbrecht 2019) (N. Sims, pers. comm. 2019).

For the bacterial pathogens and diseases (e.g. *Vibriosis*, Pseudotuberculosis, and *Streptococcus)*, antibiotics are recommended as effective (Aviles-Quevedo and Castello-Orvay 2004)—though two of the three Mexican producers state that they do not use antibiotics (Baja Seas Aquaculture 2018) (Omega Azul 2018) (T. Morris, pers. comm. 2019); the third company uses Florfenicol infrequently (The Kampachi Company 2018). Antibiotics present marketability challenges (N. Sims, pers. comm. 2019) and are generally not necessary in present production (T. Morris, pers. comm. 2019), further suggesting that disease outbreaks are not a major issue for this industry (see Criterion 4— Evidence or Risk of Chemical Use).

Regulation

Fish health in aquaculture is overseen by the National Service of Agro Alimentary Health, Safety and Quality (SENASICA), and the Mexican official standard NOM-EM-006-PESC-2004 stipulates measures to prevent the dissemination of high impact diseases, lists permitted therapeutants, and defines the standards for the use of aquaculture antibiotics and practical preventive measures to avoid epizootics (FAO 2009).

Aquaculture animal health and biosecurity is implemented by state-level aquaculture health committees. In Baja California Sur, the lead entity is *Comité de Sanidad Acuícola de Baja California Sur* (CESABCS). The CESABCS describes its mission as, *inter alia*, to prevent and control the dispersal of high impact diseases in aquaculture, to supervise the correct application of established sanitary measures and to promote the establishment of norms and state laws that allow orderly development and sustainable activity within a framework of respect for ecosystems and related activities. The CESABCS states that they monitor the animal health status for each aquaculture producer in the state and provide training on biosecurity (CSABCS 2018). The CESABCS is currently active at promoting biosecurity and fish health for the state's aquaculture industry (A. Trasviña-Moreno, pers. comm. 2019).

The federal Instituto National de Pesca (INAPESCA) recommends maintaining daily records of fish health and mortality, periodic sterilization of cages, and proper stocking strategies as best practices to promote fish health (INAPESCA 2018a) and monitoring for harmful pathogens is a condition of license (SEMARNAT 2014a)..

Conclusions and Final score

Since the quality and availability of disease data is moderate (i.e., Criterion 1 score of 5 out of 10 for the disease category), the Seafood Watch risk-based assessment was used. The *Seriola* genus generally has low susceptibility to disease in current culture conditions; however, the small scale of the current industry may be a factor. Like many aquaculture settings, the higher densities of farmed fish present some challenges to fish health, and in Mexico, parasite issues (*Neobenedenia* and *Heteraxine* skin and gill flukes) are the primary concern. Net pens are open to the surrounding environment and therefore to the exchange of pathogens and parasites from wild fish to farmed fish and vice versa. High survival rates typical of Mexican yellowtail production correspond with low disease-related mortalities, but parasite numbers are substantial, as indicated by average and peak prevalence and the regular use of pesticides. The monitoring of wild fish in Mexico is limited, and though monitoring of parasites on wild fish at a similar farm in Hawaii does not indicate the transmission of parasites from the farm, these results cannot confidently be used to assume there is a similar lack of transmission at the sites covered in this assessment in Mexico. As such, there remains a concern regarding the open nature of the production system and the discharge or pathogens and parasites. The final score for Criterion 7 – Disease is 5 out of 10.

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	
C8 Independence from unsustainable wild fisheries (0-10)	-2	
Critical?	NO	GREEN

Brief Summary

Only small numbers of wild-caught broodstock are used annually to supply hatcheries producing eggs and juveniles, and there is no use of wild-caught juveniles. With only partial replacement of broodstocks, 28% of Mexico's yellowtail production is considered dependent on wild broodstock from a source that has a greater than minimal sustainability concern. This equates to a final score for Criterion 8X Source of Stock of –2 out of –10.

Justification of Rating

All of Mexico's yellowtail producers make use of hatchery-produced fingerlings for growout, so there are no wild-caught juveniles used. One farming company (representing about 40% of Mexico's production) appears to be largely reliant on farmed broodstock, with only minimal use of wild-caught broodstock (Baja Seas Aquaculture 2018) (Rotman 2019); other Mexican producers use local wild-caught broodstock to supply eggs, cycling in low numbers (5 to 12 individuals) of new broodstock annually (Omega Azul 2018) (T. Morris, pers. comm. 2019). This results in an estimated 17 to 40% (median: 28%) annual replacement with wild broodstock, aimed at mitigating genetic risks to wild populations associated with hatchery production.

The farmed species are classified as "Least Concern" by IUCN and apparently with no known regional declines from harvesting, nor major threats to its status (IUCN 2012), though this information is somewhat dated. According to FishSource, the catch of this species in the region of interest (Baja California, Baja California Sur) is stable, with catch rates above trigger points for all regions off Northwest Mexico, though information is dated (2014) and neither the FAO nor Mexico's CONAPESCA has any newer data available. FishSource scores for Mexican Pacific yellowtail stocks are all >6 with Future Health described as "data deficient" and noting an absence of stock assessment or biomass or fishing mortality reference points. Seafood Watch notes a "moderate" concern regarding abundance of this species in the Gulf of California and Pacific regions and describes management of fisheries of this species as "ineffective" (Seafood Watch 2018).

Conclusions and Final Score

Only small numbers of wild-caught broodstock are used annually to supply hatcheries producing eggs and juveniles, and there is no use of wild-caught juveniles. With only partial replacement of broodstocks, 28% of Mexico's yellowtail production is considered to be dependent on wild broodstock from a source that has a greater than minimal sustainability concern. This equates to a final deductive score for Criterion 10X Source of Stock of –2 out of –10.

Criterion 9X: Predator and wildlife 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: aquaculture populations pose no substantial risk of deleterious effects to wildlife or predator populations that may interact with 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 Predator and wildlife mortality Final Score (0-10)	-2	
Critical?	NO	GREEN

Brief Summary

Mexican yellowtail farms are located in regions rich in wildlife. Consistent with Mexican law, producers make use of non-lethal deterrents, such as top netting, rigid mesh, regular monitoring, and prompt removal of fish mortalities. Wildlife interactions are apparently limited to non-lethal "curiosity" visits and occasional scavenging of mortalities by pinnipeds. The relevant species are not of current conservation concern. Mexican law additionally protects marine mammals and any incidental mortalities come with reporting requirements (although no data are publicly available). Although no wildlife mortalities associated with Mexican yellowtail production have been reported by the farms, and given that the occurrence of occasional entanglements is similar to net pen aquaculture systems globally, the potential for unobserved or unreported mortalities exists; thus, absent further verification, this assessment concludes that wildlife and predator mortalities may occur in exceptional cases. The final score for Criterion 9X – Wildlife Mortalities is –2 out of –10.

Justification of Rating

The Gulf of California is one of the most biologically diverse regions in the world and is its own unique ecoregion—also home to the largest protected area in Mexico. It is also one of the most important fishery regions of the eastern tropical Pacific and supports the most productive fisheries in Mexico (Erisman et al. 2010). The region hosts approximately 6,000 macrofaunal species, including over a third of the world's marine mammal species; birds—including over 170 species of seabirds; over 700 species of fish; as well as sharks and rays (SEMARNAT, pers. comm. 2014), and abundant shellfish. The area is also an important breeding ground for many species of animals, such as birds and marine mammals (Páez-Osuna et al. 2003) (Crecco 2013) (UNESCO 2018a) (WWF 2018). Further, the Gulf is home to five species of marine turtles

(SEMARNAT, pers. comm. 2014) and the world's most imperiled cetacean—the vaquita (*Phocoena sinus*) (Jaramillo-Legorreta et al. 2007). UNESCO lists the series of islands and protected areas throughout the Gulf of California (Figure 7) as World Heritage Sites (UNESCO 2018b). The value of this area as wildlife habitat is indisputable.

Similarly, the Bahia Magdalena, a lagoon complex on Baja California Sur's Pacific side is also highly productive, biologically diverse, and supports one of the state's most important fishing ports (Bizzarro 2008); the Pacific coast here is an upwelling region, and thus, highly productive (Zaytsev et al. 2003). The Baja California region is among the highest in marine mammals species richness in the world (Pompa et al. 2011). The Baja Peninsula's Pacific coastal lagoons are frequented by dolphins, sea lions, seals, turtles, breeding gray whales and migratory birds; the lagoons just 200 km to the north of Bahia Magdalena are classified as a UNESCO World Heritage Site for their ecological importance (UNESCO 2018a).

Figure 7. Southern Gulf of California. Red outlined areas denote UNESCO World Heritage sites. Yellowtail aquaculture sites are located in west-central La Paz Bay and in Bahia de Magdalena (arrows); see also *Figure 1.*

Since they act as a potential food source or shelter for wild animals, aquaculture operations will typically attract wildlife, including predators. Interactions between wildlife and fish farms are of concern as entanglements or direct control methods can be lethal (Anderson et al. 2015b). Publicly available data from other net pen aquaculture systems show some level of accidental mortality is common, even if only at a frequency of "exceptional" events (GSI 2019). Wildlife interactions can also cause significant economic loss for the farm due to direct or indirect fish losses, stress to fish, or structural damage (Anonymous 2019b).

Birds

Pelicans, frigate birds, and gulls are known to visit Mexican farms, sometimes perching on structures or inspecting penned fish (T. Morris, pers. comm. 2019). Producers here make use of an exclusionary approach to predatory birds and other wildlife via the use of bird netting—typically about 19 mm nylon mesh. Bird netting is an effective, non-lethal means to exclude birds from net pens and producers have not had to rely on lethal means to manage birds. Interaction with birds is not considered a major wildlife concern for Mexican yellowtail farming (SEMARNAT 2014a, 2014b). Producers also report that entanglement is not an issue because birds are effectively deterred from attempting to prey on fish by the presence of netting (T. Morris, pers. comm. 2019) and much of the submerged net is rigid and therefore effective at excluding diving birds (N. Sims, pers. comm. 2019). Additionally, net pens are visited at least once daily for maintenance, which provides a level of monitoring in the event of an unlikely entanglement (T. Morris, pers. comm. 2019). Both producers interviewed for this assessment state that they have never had a bird entanglement (The Kampachi Company 2018) (J. Morris, pers. comm. 2019).

Marine Mammals

Marine mammals, such as some species of dolphins, are known to avoid aquaculture areas; whales, too are thought to be repelled by such installations and there are no reports of net pen aquaculture sites directly impacting whales in Mexico. A yellowtail farm in Hawaii reports a single non-interactive whale visit to the site, and frequent, apparently benign visits from bottlenose dolphins (Sims, pers. comm. 2013, 2017, 2019). The dolphins visiting this farm feed on wild fish attracted to the structures, a phenomenon also reported elsewhere (Callier et al. 2018). Marine net pens are thought to represent more of a risk of behavioral alteration to cetaceans than a risk of injury or entanglement (though in an exceptional case, two humpback whales became entangled in net pen salmon farms in British Columbia (Vancouver Sun 2016). Rather, marine net pens may present more of an attraction to pinnipeds such as seals and sea lions (Kemper et al. 2003) (Crecco 2013).

Pinnipeds are known to damage gear in attempts to prey upon net pen stocks, generally, with otariids like fur seals and sea lions being responsible for most marine mammal interactions with farms. Such interactions may result in extensive damage and loss for the farmer—and lethal interaction through entanglement or permitted/unpermitted killing (Kemper et al. 2003) (Callier et al. 2018). There are some reports of marine mammals being entangled in aquaculture gear (Northridge et al. 2013), but none in Mexico (noting that there are no publicly available data) and overall there is little quantitative data available to understand this potential issue in net pen aquaculture (Callier et al. 2018).

A Hawaiian yellowtail farm reports very rare visits from seals, with a single mortality in exceptional circumstances in a non-stocked pen undergoing maintenance (N. Sims, pers. comm. 2019). New Zealand, which has yellowtail farms, reports no records of marine mammal entanglements in such structures and that this can be avoided with proper tensioning of lines and anti-predator nets, using small mesh size, and managing waste (Baker 2005), approaches that have proven effective elsewhere globally, especially when coupled with strategic farm siting (Callier *et al.* 2018).

Baja California waters are home to four pinniped species: California sea lions, Guadeloupe fur seals, northern elephant seals, and harbor seals on the Pacific coast and primarily California sea lions within the Gulf of California (Gallo-Reynoso et al. 2010). Producers in Mexico report occasional benign "curiosity" visits from pinnipeds and occasional pulling of dead fish from the bottom of the nets, but no detrimental interactions with net pen structures or farmed fish (T. Morris, pers. comm. 2019) (N. Sims, pers. comm. 2019). One producer reports that net pen structures have been damaged by sea lions scavenging dead fish at the bottom (Anonymous 2019b). A colony of sea lions has taken up residence at one farm and is known to scavenge dead fish from the bottom of the pen, but to date the copper-alloy mesh has been resilient to damage or harm to sea lions (The Kampachi Company 2018).

Each of these pinniped species is an IUCN species of "Least Concern" with all but the harbor seal experiencing increasing populations (harbor seal population trends are unknown) (IUCN 2018). Marine mammals are protected in Mexico by The Fisheries Law and lethal take is banned (SEMARNAT 2014b) (T. Morris, pers. comm. 2019) (N. Sims, pers. comm. 2019). Violation can result in the forfeiture of a farming license and is punishable by a 1 to 9 year prison sentence under Mexican law (Zertuche-González et al. 2008). An environmental impact assessment of one farm concluded that sea lions would be the most likely predator to interact with a proposed yellowtail farm, and that they could be effectively excluded non-lethally (SEMARNAT 2014b), which aligns with producer reports.

<u>Fish</u>

There is little information available on interactions between wild fish and Mexican yellowtail farms, though the possibility exists. For open ocean farming of *S. rivoliana* in Hawaii, for example, aggregation of wild fish at the farm site occurs—with the structures serving as habitat for a wide diversity of resident and transient species. It does not appear that attracted wild fish being eaten by farmed yellowtail is a serious threat to populations of attracted fish; escaped farmed yellowtail, though, are quickly eaten by fish attracted by the net pen structure (Sims 2017). The Hawaiian farm also notes occasional visits (and net pen entry) from sharks, attracted by live and dead fish, and leading to only one lethal removal, since nonlethal means are effective at dealing with the limited shark encounters (Sims 2013); similar interactions are described for cobia farming in Panama (Seafood Watch 2017a). Farms are generally thought to benefit wild fish abundance through trophic subsidy and habitat provision, although impacts to migration patterns and consequences of farm structures (and food provision) on wild fish behavioral changes are not well understood (Callier et al. 2018). One Mexican company reports that in contrast to the Hawaiian farm, their Gulf of California farm has not yet been observed to attract or aggregate fish. Sharks have visited, though no harmful interactions between shark and farm are believed to have occurred (The Kampachi Company 2018).

Regulation and Management

Mexican law permits only non-lethal means of controlling predators—such as acoustic and visual deterrents (T. Morris, pers. comm. 2019) (SEMARNAT 2014b), though acoustic devices are viewed as ineffective long-term and disruptive to area wildlife, and thus not used by at least one company (T. Morris, pers. comm. 2019). Permit conditions direct operators to release or rescue wildlife encounters in aquaculture structures—both those species of conservation concern outlined in NOM-059-SEMARNAT-2010, and those that aren't (SEMARNAT 2014a). Mexican guidelines recommend use of strong nets for deterring waterborne predators and anti-predator coverings to exclude birds (Aviles-Quevedo and Castello-Orvay 2004), with which the industry complies. Wildlife interactions with aquaculture operations are required to be documented and reported to the Mexican government (SEMARNAT 2014b), but this data does not appear to be publicly available.

Producers mitigate the risk of interaction with predators in the nursery stage by covering tanks to protect young fish. During growout, all Mexican producers make use of covered net pens to exclude aerial predators (Baja Seas Aquaculture 2018) (T. Morris pers. comm. 2019) (N. Sims pers. comm. 2019).

For pinnipeds like sea lions, management measures are reported by industry as largely effective: use of 4 mm wire mesh and steel-reinforced top mesh are effective at excluding sea lions from pens (N. Sims, pers. comm. 2019). Producers also monitor for and remove dead fish regularly to manage potential attractants (T. Morris, pers. comm. 2019) (N. Sims, pers. comm. 2019) and some have installed 1 m high freeboard fencing around the tops of cages (SEMARNAT 2014b) (Omega Azul 2018).

Producers also train employees on wildlife interactions and on the use of non-lethal deterrence. Any accidental wildlife mortalities are recorded in logs and reported to the Mexican government (SEMARNAT 2014a) and at least one company states that they make this information available to the public (T. Morris, pers. comm. 2019), though these reports could not be located for this assessment. One producer provided a copy of their predator management protocols—affirming commitment to non-lethal deterrence (T. Morris, pers. comm. 2019).

Figure 8. Example of yellowtail net pen in Bahia de Magdalena with apparently effective avian predator exclusion design. (Aviles-Quevedo and Castello-Orvay 2004).

Mexican yellowtail producers report that their approach of prioritizing exclusion to manage potential conflict with wildlife is completely effective, obviating the need for lethal control measures, and that wildlife entanglement or entrapment have thus far not been issues, though this is difficult to verify. Third-party experts have also stated that wildlife mortalities are not an issue for this industry (F. Rotman, pers. comm. 2019) (K. Stuart, pers. comm. 2019). No direct or accidental wildlife mortalities associated with Mexican yellowtail production have been reported, and although further verification would address the uncertainty, this assessment assumes that wildlife and predator mortalities are indeed of “low” concern.

Conclusions and Final Score

The region in which Mexican yellowtail is produced is rich in wildlife. Consistent with Mexican law, producers make use of non-lethal deterrence methods, such as top netting, rigid mesh, regular monitoring, and management of fish mortalities. Wildlife interactions are reported by the producers to be limited to nonlethal “curiosity” visits and occasional scavenging of mortalities by pinnipeds; species likely to visit are not of present conservation concern. Mexican law also protects marine mammals and any incidental mortalities come with reporting requirements (though data are not publicly available). Although no wildlife mortalities associated with Mexican yellowtail production have been reported by the farms, given that the occurrence of occasional entanglements is similar net pen aquaculture systems globally, the potential for unobserved or unreported mortalities exists; absent further verification, this assessment concludes that wildlife and predator mortalities are most likely limited to exceptional cases. Therefore, the final score for Criterion 9X – Wildlife Mortalities is a minor deduction of –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
- Impact: aquaculture operations by design, management or regulation avoid reliance on the movement of live animals, therefore reducing the risk of introduction of unintended species.

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 (%)	0	
F10Xb Biosecurity of source/destination	10	
C10X Escape of secondary species Final Score	**0**	**GREEN**

Brief Summary

Mexican yellowtail fingerlings are produced in modern, domestic hatcheries, and do not require imports or trans-waterbody shipments of live fish or eggs. As such, risk of escape of unintentionally introduced species with this industry is low. The final score for Criterion 10X – Escape of secondary Species is –0 out of –10.

Justification of Rating

<u>Factor 10Xa International or trans-waterbody live animal shipments</u>

Early in the development of the Mexican yellowtail industry, fingerlings were initially imported from a hatchery in San Diego, California, USA, but now are supplied by domestic hatchery production (Baja Seas Aquaculture 2018) (Omega Azul 2018) (King Kampachi 2019). All Mexican production is supplied by three domestic hatcheries; all companies producing yellowtail in Mexico are vertically integrated and require no international or trans-waterbody shipment of animals (Baja Seas Aquaculture 2018) (Omega Azul 2018) (King Kampachi 2019). The use of domestic hatcheries means that the trans-regional shipment of fish and fingerlings advised against by Purcell et al. (2015) is unnecessary for this industry. The score for Factor 10Xa is 10 out of 10, which means Factor 10Xb is not assessed.

Conclusions and Final Score

Mexican yellowtail fingerlings are produced in modern, domestic hatcheries, precluding reliance on imports or trans-waterbody shipments. As such, risk of escape of unintentionally introduced species with this industry is low. The final score for Criterion 10X – Escape of Secondary Species is a deduction of –0 out of –10.

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About Seafood Watch®

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

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

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

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

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Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[7] or farmed that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

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

Seafood Watch will:

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

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

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

Once a score and 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.

Appendix 1 - Data points and all scoring calculations

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

Criterion 1: Data quality and availability

Data Category	Data Quality (0-10)
Industry or production statistics	7.5
Management	7.5
Effluent	7.5
Habitats	7.5
Chemical use	7.5
Feed	7.5
Escapes	7.5
Disease	5
Source of stock	10
Predators and wildlife	5
Unintentional introduction	10
Other – (e.g. GHG emissions)	n/a
Total	**82.5**

C1 Data Final Score (0-10)	**7.5**	**GREEN**

Criterion 2: Effluents

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**7**	**GREEN**
Critical?	NO	

Criterion 3: Habitat

Factor 3.1. Habitat conversion and function

F3.1 Score (0-10)	8

Factor 3.2 – Management of farm-level and cumulative habitat impacts

3.2a Content of habiat management measure	3
3.2b Enforcement of habitat management measures	3
3.2 Habitat management effectiveness	**3.6**

C3 Habitat Final Score (0-10)	**7**	**YELLOW**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	**Score**	
C4 Chemical Use Score (0-10)	**6**	
C4 Chemical Use Final Score (0-10)	**6**	**YELLOW**
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Feed parameters	**Score**
5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	36.7
Fishmeal from byproducts (%)	37.7
% FM	22.8641
Fish oil inclusion level (%)	12.4
Fish oil from byproducts (%)	56.2
% FO	5.4312
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.36
FIFO fishmeal	1.38
FIFO fish oil	1.48
FIFO Score (0-10)	**6.31**
Critical?	NO
5.1b Sustainability of Source fisheries	
Sustainability score	-2
Calculated sustainability adjustment	-0.59
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**5.72**

Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	45
eFCR	1.36
Feed protein from fishmeal (%)	
Feed protein from EDIBLE sources (%)	79.55
Feed protein from NON-EDIBLE sources (%)	20.45
Protein OUTPUTS	
Protein content of whole harvested fish (%)	21.7
Edible yield of harvested fish (%)	79
Use of non-edible byproducts from harvested fish (%)	33
Total protein input kg/100kg fish	61.2
Edible protein IN kg/100kg fish	48.69
Utilized protein OUT kg/100kg fish	25.96
Net protein gain or loss (%)	-46.68
Critical?	NO
F5.2 Net protein Score (0-10)	**5**

5.3. Feed Footprint

5.3a Ocean Area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	49.1
eFCR	1.36
Carbon required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Ocean productivity (C) for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	17.37
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	50.9
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.36
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.26
Total area (Ocean + Land Area) (ha)	17.63
F5.3 Feed Footprint Score (0-10)	4

Feed Final Score

C5 Feed Final Score (0-10)	**5.11**	**YELLOW**
Critical?	**NO**	

Criterion 6: Escapes

6.1a System escape Risk (0-10)	4	
6.1a Adjustment for recaptures (0-10)	3	
6.1a Escape Risk Score (0-10)	**7**	
6.2. Invasiveness score (0-10)	**8**	
C6 Escapes Final Score (0-10)	**7**	**GREEN**
Critical?	**NO**	

Criterion 7: Diseases

Disease Evidence-based assessment (0-10)		
Disease Risk-based assessment (0-10)	5	
C7 Disease Final Score (0-10)	**5**	**YELLOW**
Critical?	NO	

Criterion 8X: Source of Stock

C8X Source of stock score (0-10)	-2	
C8 Source of Stock Final Score (0-10)	**-2**	**GREEN**
Critical?	NO	

Criterion 9X: Wildlife and predator mortalities

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

Criterion 10X: Escape of unintentionally introduced species

F10Xa live animal shipments score (0-10)	10.00	
F10Xb Biosecurity of source/destination score (0-10)	0.00	
C10X Escape of Unintentionally Introduced Species Final Score (0-10)	**0.00**	**GREEN**
Critical?	n/a	