Monterey Bay Aquarium
Seafood Watch®

Sablefish

Anoplopoma fimbria

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British Columbia, Canada

Open Marine Net Pens

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Seafood Watch Consulting Researcher

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

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

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished[1] or farmed that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

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

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

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

impacts on wild fish and ecosystems that may result from the escape of native, non-native and/or genetically distinct farmed species.

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

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

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

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

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

Final Seafood Recommendation

Criterion	Score	Rank	Critical?
C1 Data	7.50	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	6.27	YELLOW	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	6.73	GREEN	NO
C6 Escapes	6.00	YELLOW	NO
C7 Disease	6.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-1.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**47.50**		
Final score (0-10)	**6.79**		

OVERALL RANKING

Final Score	6.79
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK
GREEN

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 numerical score for sablefish farmed in net pens in British Columbia, Canada is 6.79 out of 10, which is in the Green range. With no Red criteria, the final ranking is Green and a recommendation of Best Choice.

Executive Summary

The total global volume of farmed sablefish harvested in 2018 was around 330 MT, all of which was produced in British Columbia, Canada. This low production volume demonstrates that this industry is still in its infancy, however, the high market value of this species, combined with declining wild-capture volumes has encouraged the development of this niche sector. At the time of writing, there is only one commercial-scale, net-pen producer of sablefish; this company has two on-growing sites and one hatchery site, all of which are located in the vicinity of Vancouver Island, British Columbia. Given this status, the majority of data considered in this report pertains to this single producer and the governance framework and arrangements that support it. While Japan is by far the biggest importer and consumer of wild-caught sablefish, the US is presently the largest volume importer of farmed sablefish, typically absorbing 50% of the operating company's annual production.

This Seafood Watch assessment involves a number of different 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.

<u>Criterion 1 – Data</u>
Much of the data to inform this assessment has been provided directly by a single company. While the farm was cooperative in providing the data deemed necessary to inform this assessment, these data were generally not independently verified. These data are comprised of both personal communications with the company and also company reports, which are part of the license-holder requirements stipulated by the Department of Fisheries and Oceans (DFO), the principle agency responsible for oversight of aquaculture activities in British Columbia (BC). These reports cover an array of aspects pertaining to the company's performance, some of which are prepared either in-house or by contracted third-parties, dependent upon government requirements. Although the farming of sablefish is an emergent sector, and the quantity of relevant peer-reviewed literature was limited, the literature that was available in this regard was considered to be robust and of a high standard. Overall, three data categories scored 10 out of 10 (Industry and Production Statistics, Management and Regulations, and Escape of Secondary Species), five data categories scored 7.5 out of 10 (Effluents, Habitat, Chemical Use, Source of Stock, and Wildlife and Predator Mortalities), whereas three data categories scored 5 out of 10 (Feed, Escapes, and Diseases). When all of these are taken into consideration, the final score for Criterion 1 – Data is 7.5 out of 10.

<u>Criterion 2 – Effluent</u>
The environmental fate of fish farm effluents has been well-studied in many parts of the world and it has been demonstrated that effective site selection does much to mitigate negative impacts caused by the dispersal of such wastes. The primary government agency responsible for overseeing the licensing, regulation and monitoring of aquaculture activities in the Province of BC is the department of Fisheries and Oceans Canada (DFO). Part of the DFO's regulatory

requirements for fish farms is that benthic monitoring is regularly conducted and reported upon; farms generally hire an independent contractor to perform this work and the DFO may subsequently conduct audits to verify these results. Although these benthic surveys are of particular relevance to the Habitat Criterion, they are also relevant to this Effluent Criterion since they incorporate data collection that extends significantly beyond the farm boundary, up to a distance of 140 m. A review of the operating company's biennial monitoring survey reports demonstrate that they have always remained well within the government's compliance criteria. There is, however, no equivalent regulatory requirement for monitoring effluents in the water column. Since sablefish farming is not a well-developed industry, there is not a great deal of peer-reviewed data available specific to the sector, however, one BC sablefish farm study was identified, which analysed suspended particulate wastes in the water column. This study found that while suspended particulate wastes were detectable between depths of 1 - 3 m within the cage during feeding, no such waste signal was detected outside the cage structure: the area included in the analysis extended out to a distance of 500 m and down to a depth of 25 m. This finding aligns with a large body of literature regarding the potential effluent impacts of marine finfish aquaculture, salmon in particular, in net pens globally. In light of the operating company's low production volumes, their ongoing regulatory compliance with monitoring surveys, and the fact that there are no other operational farms within a 3 km radius, the farm's activities are not considered to contribute to local and regional nutrient loads. The final score for Criterion 2 – Effluent is 8 out of 10.

<u>Criterion 3 – Habitat</u>

Aquaculture cage installations typically do not cause direct habitat impacts. However, if fish feces and uneaten food are not adequately dispersed, and subsequently accumulate on the benthos under and around the net pen, they can have significant, measurable habitat impacts. With regard to the potential environmental impacts of marine farms in BC and their regulation, the content of habitat management measures that are in place at the farm-level are considered to be robust and regulation of the sector is based on maintaining ecosystem functionality of the habitats in which fish farms are sited. These management measures require that farms perform benthic monitoring and report these data to the DFO on an ongoing, scheduled basis; if performance thresholds are breached, sites must be fallowed until benthic remediation has been effected. According to data provided by the operating company, the functionality of the benthic habitats located within the AZEs of their two farm sites are considered to be maintained, exhibiting only minor impacts – although the last DFO audit performed to verify the company's status in this regard took place in 2014. While governance at the farm-level appears to be robust, management and enforcement measures to explicitly address cumulative industry impacts at the regional-level in BC is evidently limited. This results in a final Criterion 3 – Habitat score of 6.27 out of 10.

<u>Criterion 4 – Chemical Use</u>

Given the small size of the sablefish aquaculture industry, there is not a great deal of general data available concerning the sector's chemical usage. Most information used to inform this Criterion was therefore obtained from DFO materials and from data provided directly by the only presently active commercial net pen producer of sablefish. Farmed sablefish do not typically suffer from parasites thus parasiticides are not required during production. The main pathogen that afflicts cultured sablefish is furunculosis; bespoke sablefish vaccines to counteract this disease are in development and are reportedly becoming more effective, however, a range of government approved antibiotics have been used by the industry to combat this ailment in recent years. When used, these drugs have been administered under the direction of a veterinarian and in accordance with a federally approved fish Health Management Plan (HMP). Canadian fish farm operators are required to report their drug use to DFO, and this information is subsequently made publicly available on DFO's National Aquaculture Public Reporting web page; at the time of writing, datasets for 2016 and 2017 are assessable through this portal. The records of the farm currently in production, indicate that antibiotics have been used on a number of individual cages during some production cycles but, taken cumulatively, these data show that chemical treatments are used on average less than once per year at each site. Since these treatments are administered into open net pens, this inevitably allows their release into the environment. But, when treatments are used less than once per year, this results in a low overall concern according to the Seafood Watch Standard. In order to verify that drug usage reporting is accurate and that HMPs are being adhered to, the DFO perform site inspections and publicly report on the sector's compliance in this regard. During production, the operating company use a number of other chemicals, asides from antibiotics, which include disinfectants for routine cleaning as well as a government approved anaesthetic, none of which are considered to present an ecological risk. Overall, the available data indicate that chemical treatments are used, on average, less than once per year and this results in a score of 8 out of 10 for Criterion 4 – Evidence or Risk of Chemical Use.

Criterion 5 – Feed

Since there is presently only one global, commercial net pen producer of sablefish, data to inform this Criterion were provided by this company's feed supplier and confirmed by information found in the literature. The economic FCR supplied by the company is 1.45, which is aligned with data otherwise identified in scientific literature. The calculated Feed Fish Efficiency Ratio (FFER) for farmed sablefish is 7.32 out of 10 and this, combined with a Sustainability of the Source of Wild Fish score of -4 out of -10, results in an overall Factor 5.1 score of 6.47 out of 10. Protein in feeds used for the company's farmed sablefish are sourced from 17.06% marine ingredients, 18.75% crop ingredients and 46.41% land animal ingredients, however, 61.94% of these protein inputs are considered to come from sources not suitable for human consumption. Extrapolated feed calculations demonstrate a net edible protein loss of 16.69%, which provides an overall score of 8 out of 10 for Factor 5.2. The calculated feed footprint for production of one MT of farmed sablefish is 11.73 hectares, which results in an overall Factor 5.3 score of 6. Taken together, Factors 5.1, 5.2 and 5.3 combine to give a final Criterion 5 – Feed score of 6.73 out of 10.

Criterion 6 – Escapes

By design, open net pen aquaculture systems are vulnerable to escape events. Robust management measures, in conjunction with the effective implementation of Best Management Practices (BMPs), can greatly diminish the potential for escapes to happen, and mitigate the severity of ensuing ecological consequences, should they occur. In order to remain licensed, all marine farms in BC must implement BMPs with regard to escapes by having an approved 'Escape Prevention and Response Plan' in place. Any escapes that do occur must be promptly reported by farm operators to DFO, which in turn make these data publicly available. To date, these public records do not include any incidents of farmed sablefish escaping. The operating company also attest that they have never knowingly had an escape event. While no escapes have ever been documented by the sector, and it is evident that BMPs are actively employed by the current industry, the Seafood Watch Standard nevertheless considers the potential risk of escapes occurring to be low-moderate since monitoring data in this regard cannot be robustly verified. However, according to the Standard, the ecological risk presented by such an eventuality is considered to be low. This is concluded because sablefish, which exhibit a high degree of genetic homogeneity throughout their range, are a native species in the waters of BC and, in addition to this, the broodstock used by the current industry are primarily wild-caught (80%), with the balance being the progeny of wild parents. When all of these factors are considered together, the final score for Criterion 6 – Escapes is 6 out of 10.

<u>Criterion 7 – Disease</u>

Literatures notes that sablefish is typically a hardy species; mortality data obtained from the sablefish sector indicates that less than 1% of farmed stocks succumb to disease, in respect of fish > 500g. The main disease that affects farmed sablefish is furunculosis, the causative agent of which is the bacterium *Aeromonas salmonicida*. Susceptibility to *Vibrio anguillarum* has also been demonstrated in disease exposure challenge studies with this species. The operating company have been using a furunculosis vaccine developed for Atlantic salmon with some success, and they are also collaborating with a Canadian lab to develop a bespoke sablefish vaccine for furunculosis, using bacterial isolates from the water body in which their farm is located. Research into the development of vaccines to protect sablefish against furunculosis is also taking place in the US. The conditions of license for marine farm operators in BC clearly stipulate a range of biosecurity measures and reporting requirements that must be followed by farms, including development of, and adherence to, a DFO approved fish Health Management Plan (HMP) plus the provision of regular reports detailing the health of fish stocks. Farm facilities may also be inspected to ensure their compliance in this regard. While no studies were identified that assessed the flow of pathogens between farmed sablefish and wild conspecifics - and despite the inherent design of open net pens that make this bidirectional flow of pathogens highly probable - it is unlikely that the current small-scale of the sablefish industry is a cause for concern in terms of the on-farm amplification and retransmission of disease to wild fish, particularly given that the present status of wild stocks is reportedly healthy. It is thus considered that the fish health management measures implemented by the current industry result in low, temporary or infrequent occurrences of infections or mortalities at the 'typical' farm level and the final score for Criterion 7 – Disease is 6 out of 10, which reflects a low-moderate concern for this aspect of production.

<u>Criterion 8X – Source of Stock</u>

The present solo commercial producer of farmed sablefish supply their two on-growing cage sites with juveniles produced in their own hatchery. The company also have an on-site broodstock program, however this facility is still reliant to a large extent on wild-caught broodstock. Approximately 80% of the broodstock used to produce juveniles come from wild fisheries, since the technology needed to use 100% domesticated broodstock is still in development. The wild broodstock that the company catch come from local fisheries that are considered to be a 'Good Alternative – Yellow' choice by the Seafood Watch program, with a 'Green' stock status ranking. As such there is no deduction for this Criterion and the score for Criterion 8X – Source of Stock is of 0 out of -10.

<u>Criterion 9X – Wildlife and Predator Mortalities</u>

At the industry-wide level, data show that wildlife and predator mortalities caused by interactions with marine farm installations in BC are limited to exceptional cases. Notably, impacts on marine mammals have declined dramatically across the sector in recent years. Although the operating company do experience predator and wildlife interactions at both of their farm sites, the low stocking densities used likely pose less of an attractant than those employed by more intensive production systems and effective management and prevention measures would appear to be in place. The company have not reported any wildlife or predator mortalities over the last 5 years, asides from the occasional mortality of incidentally caught wild fish. All incidental capture of wild fish in marine net pens in BC must be documented and reported upon to DFO and farmers must also release these incidentally caught wild fish in accordance with regulations. Although the majority of wild fish that are incidentally captured in this way are released unharmed, the details of any mortalities that do occur in this regard are made publicly available on DFO's website. A review of these online data indicate that the operating company have reported a number of incidents of wild fish being killed accidentally in this fashion; all of these species are from healthy stocks, asides from the copper rockfish, which is placed in the 'Avoid' category in Seafood Watch's wild capture recommendations. The number of copper rockfish impacted in this way is low, however, and is not considered to have a significant, detrimental effect on wild fish populations. The Seafood Watch Standard makes no scoring deduction when there is "*No direct or accidental mortality of predators or wildlife,*" however, to account for the limited impact on copper rockfish, a deduction of 1 has been made and the final score for Criterion 9X – Wildlife and Predator Mortalities is -1 out of -10.

<u>Criterion 10X – Escape of Secondary Species</u>

Production of farmed sablefish in BC, Canada is not considered to present a risk with regards to the unintentional trans-waterbody shipment of non-native species, since movements of juveniles and broodstock are limited to the local area. Because no deduction is warranted, the assessed score for Criterion 10X – Escape of Secondary Species is 0 out of -10.

When all of the above criteria are considered together, the final numerical score for sablefish farmed in net pens in British Columbia, Canada is 6.79 out of 10, which is in the Green range. With no Red criteria, the final ranking is Green and a recommendation of Best Choice.

Introduction:

Scope of the analysis and ensuing recommendation

Species
Sablefish, *Anoplopoma fimbria*

Geographic Coverage
British Columbia, Canada

Production Method
Open Marine Net Pens

Species Overview
The Anoplopomatidae Family is comprised of two species of scorpaeniform fishes, namely the sablefish, *Anoplopoma fimbria* and the skilfish, *Erilepis zonifer* (ARFM 2017, Mecklenburg 2003), both of which inhabit deep water regions of the northern Pacific. The sablefish is typically found over muddy bottoms and slopes at depths of 200 - 1,500 meters (Rondeau et al. 2013), although juveniles have a pelagic stage during which they frequent surface and inshore waters (Froese & Pauly 2019). In their most northerly range, sablefish inhabit the Bering Sea where they can be found off the coasts of Alaska, Russia and Kamchatka. They are evidently most abundant in the Gulf of Alaska (NOAA 2018, NOAA 2010), from where their range extends southward, along the North Pacific Ocean's continental shelf, to Mexico's Baja California Peninsula in the eastern Pacific and westward along the Aleutian Islands chain toward Japan. Little is known about the spawning habits and spawning locations of sablefish (Fenske et al. 2019). Sablefish are opportunistic feeders and their diet consists of worms, cephalopods, crustaceans and fish (Mecklenburg 2003). Sperm whales are likely one of the main species that predate upon sablefish (ARFM 2017). They are a long-lived species, attaining a maximum recorded age of 94 years (Fenske et al. 2019). The maximum recorded length for sablefish is 1.2 meters, although 0.8 meters is the average length of a mature individual (Froese & Pauly 2019). The maximum documented weight for this species noted in recent literature is 14 kg for females and 6.8 kg for males (NOAA 2010), however, earlier literature documents a maximum weight of 57 kg for this species (Sumaila et al. 2007, Eschmeyer et al. 1983). Sablefish display sexual dimorphism, such that females grow faster and larger than males (Guzmán et al. 2017, Luckenbach et al. 2017, Rondeau et al. 2013).

Production system
Presently, BC's sole commercial marine net-pen producer of sablefish uses juveniles produced at their land-based marine hatchery, which operates year-round (Leeuwis 2017, HI 2016, ANA 2013). Once nursery fish attain a size of 30 - 50 g, at around four months old, they are transferred to sea to be on-grown in square, steel net pens at one of the company's two licensed farm sites in Kyuquot Sound on the northwest of Vancouver Island, the general location of which can be seen in Figure 1. These sites are called Charlie's Place and Whiteley

Island; the former is licensed for a maximum annual production of 2,700 MT and contains 12 pens, whereas the latter is licensed for up to 2,202 MT[2], accommodating 8 cage units (both cage fields comprise a total area of 30 m x 30 m). Each net pen has a capacity of 22,500 m^3 and the stocking densities employed are typically very low, never exceeding 10 kg/m^3. Once transferred to the net pens, fish take approximately 20 months to reach harvest size; thus, the entire production cycle takes around 2 years. Upon harvesting, the fish are graded into two size classes: 4/6, which average 5.5 lbs (2.5 kg) and 6/8, which average 7.1 lbs (3.2 kg) (pers. comm. Claire Li, GESF, July 2019).

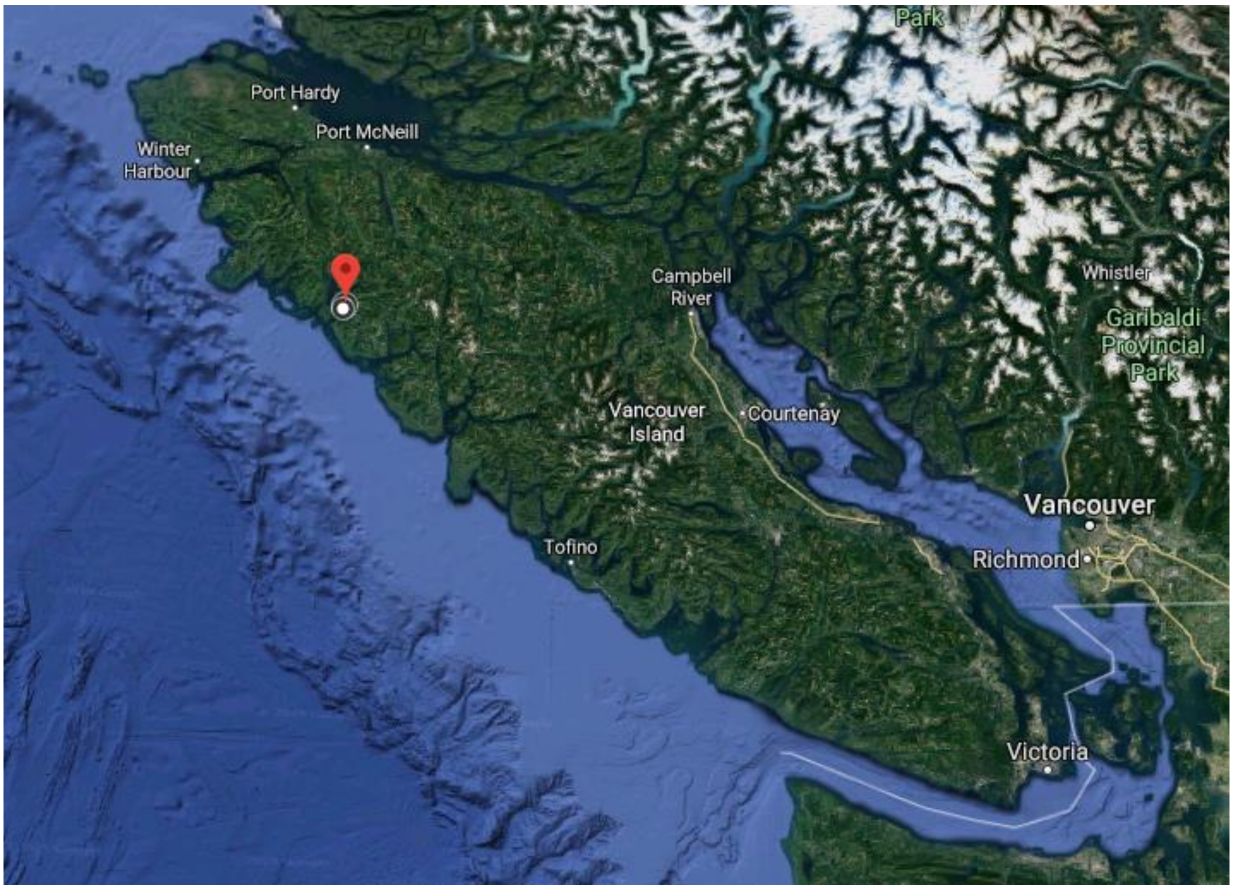

Figure 1: Map showing the location of the operating company's two marine farm sites in Kyuquot Sound, Vancouver Island, British Columbia, Canada (Map data © 2019 Google)

While the hatchery phase of production inevitably results in some degree of effluent discharge, the lengthier on-growing phase, which takes place in open water, presents greater potential for environmental impacts arising from effluents, diseases and chemical use, thus it is this phase of production that the following assessment focuses on. For further reference, a map showing all of BC's licensed marine finfish aquaculture facilities, including the sablefish farm sites under consideration, is available on the DFO website[3].

[2] https://open.canada.ca/data/en/dataset/522d1b67-30d8-4a34-9b62-5da99b1035e6
[3] http://www.dfo-mpo.gc.ca/aquaculture/bc-cb/docs/maps-cartes/mar-eng.pdf

Production statistics and the impetus for the development of sablefish aquaculture
Research into the viability of sablefish as a potential aquaculture candidate was initiated in the mid-1960s using wild-caught juveniles. This work was conducted at the Pacific Biological Station on Vancouver Island, a research facility run by the Canadian Department of Fisheries and Oceans (DFO) (HI 2016). While the species was found to adapt well to confinement and growth rates were good, the difficulty in obtaining a consistent supply of wild-caught juveniles was identified as a constraint to further progress (AAC 2013). Later, in the mid-1980s, efforts toward the development of larval rearing techniques for sablefish (Jensen et al. 1992) reignited interest in cultivation of this species and, in 1998, the first cultured juveniles were produced (Reid et al. 2016, AAC 2013, Clarke et al. 1999). To date, however, commercial production of sablefish has been minimal, with production volumes not yet reflected in FAO global production data (FAO 2019). Indeed, since cultured sablefish represents only a small proportion of overall Canadian aquaculture production, volumes of this species are generally not disaggregated in publicly available national production statistics: DFO's 2017 statistics aggregate sablefish production into an 'other' category, which amounts to 453 MT[4], representing 0.52% of annual farmed production for that year – whereas farmed salmon accounted for over 98% of production.

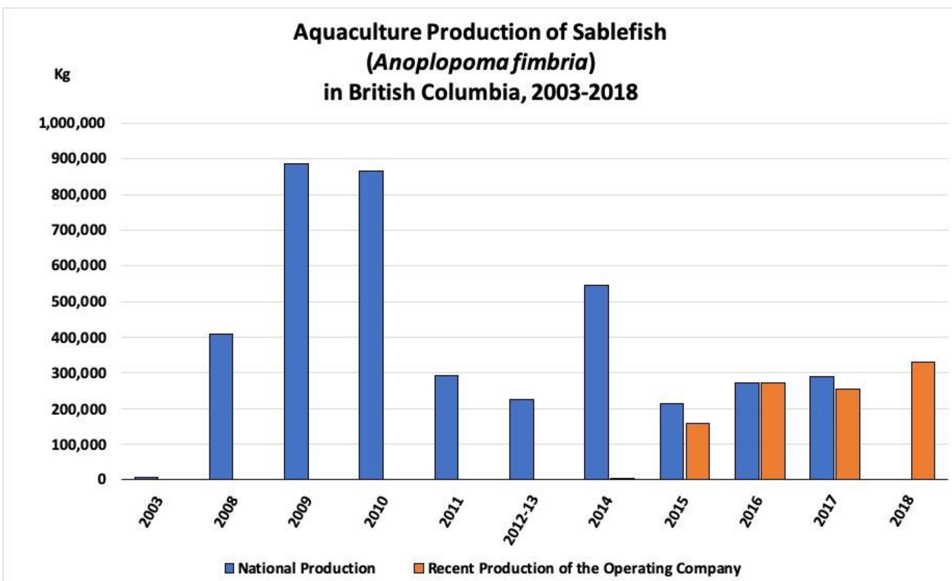

Figure 2: An overview of Canada's total sablefish production from 2003 to 2018 (in blue) in contrast with that of the current solo commercial net pen producer (in orange) (pers. comm. Claire Li, GESF, May 2019; Michelle Manning, DFO August 2019; James Dalby, Ministry of Agriculture BC, August 2019)

Figure 2 shows the sablefish production statistics that were obtained via personal communications with the provincial government in BC (years 2003 to 2010) and the DFO (years 2011 to 2017); these data are presented in blue. The data presented in orange shows the production volumes of BC's only current commercial net pen producer of sablefish, which clearly demonstrates their present dominance of the sector (CAIA 2019); indeed, at this time,

[4] http://www.dfo-mpo.gc.ca/stats/aqua/aqua17-eng.htm

this company is the sole commercial-scale, global producer of this species. Although this enterprise has been culturing sablefish for 12 years (ANA 2017), the current company structure was established in November 2014 and it is the annual production of this commercial entity that is shown in Figure 2, alongside national production statistics.

Note that in Figure 2, national production data for some years is missing, since there is a requirement that there must be at least 3 producers in order for annual volumes to be publicly released (this is also why years 2012 and 2013 have been combined). Since the DFO only started managing aquaculture data in 2011, data from this year forward was provided by them, whereas data prior to 2011 was obtained from the BC Ministry of Agriculture.

Of note, although there is no commercial aquaculture production of sablefish in the US, a pilot study is currently underway in Washington State at the National Oceanic and Atmospheric Administration's (NOAA) Manchester Research Station[5] (Cook et al. 2017) and trials in recirculating aquaculture systems (RAS) are also being conducted in Texas (Goetz & Parsons 2019, Leeuwis 2017, ANA 2017) by the Perciformes Group[6].

Import and export sources and statistics

A review of the sablefish sector by the National Oceanic and Atmospheric Administration (NOAA) Fisheries Office identifies Japan as the world's largest importer and consumer of this species, further noting that this nation imported over two thirds of total global landings in 2012 (NOAA 2014). Japan no longer has a commercial fishery for sablefish and last reported wild capture of this species to FAO in 1985 (FAO 2019), thus Japanese imports predominantly hail from the US where the vast majority of sablefish are caught (NOAA 2014). While a large quantity of BC's farmed sablefish is also destined for the Japanese market (40%), half of the sector's current production is typically exported to the US (50%) and the balance (10%) is retained on the domestic Canadian market (pers. comm. Claire Li, GESF, May 2019).

Common and market names

Table 1: Source - FishBase Catalogue of Life: 2019 Annual Checklist (Froese & Pauly 2019)

Scientific Name	*Anoplopoma fimbria*
Common Name	Sablefish (Canada, USA) Black cod (Canada, USA, UK) Gindara (Japan) Coalfish or Charbonnier commun (Canada) Coal cod (UK)

Product forms

US & Canada: head-on, gutted, fresh; frozen fillets, vacuum packed

Japan: head-on, gutted, fresh; frozen J-cut

[5] https://www.fishwatch.gov/profiles/sablefish-farmed
[6] https://perciformesgroup.com

Criterion 1: Data quality and availability

Impact, unit of sustainability and principle

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

Criterion 1 Summary

Data Category	Data Quality	Score (0-10)
Industry or production statistics	10	10
Management	10	10
Effluent	7.5	7.5
Habitat	7.5	7.5
Chemical use	7.5	7.5
Feed	5	5
Escapes	5	5
Disease	5	5
Source of stock	7.5	7.5
Predators and wildlife	7.5	7.5
Escape of secondary 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

Much of the data to inform this assessment has been provided directly by a single company. While the farm was cooperative in providing the data deemed necessary to inform this assessment, these data were generally not independently verified. These data are comprised of both personal communications with the company and also company reports, which are part of the license-holder requirements stipulated by the Department of Fisheries and Oceans (DFO), the principle agency responsible for oversight of aquaculture activities in British Columbia (BC). These reports cover an array of aspects pertaining to the company's performance, some of which are prepared either in-house or by contracted third-parties, dependent upon government requirements. Although the farming of sablefish is an emergent sector, and the quantity of relevant peer-reviewed literature was limited, the literature that was available in this regard was considered to be robust and of a high standard. Overall, three data categories scored 10 out of 10 (Industry and Production Statistics, Management and Regulations, and Escape of Secondary Species), five data categories scored 7.5 out of 10 (Effluents, Habitat, Chemical Use, Source of Stock, and Wildlife and Predator Mortalities), whereas three data categories scored 5 out of 10 (Feed, Escapes, and Diseases). When all of these are taken into consideration, the final score for Criterion 1 – Data is 7.5 out of 10.

Justification of Ranking

Industry and Production Statistics

Since cultured sablefish production is presently a nascent, niche sector of the global aquaculture industry, production statistics are not yet recorded in FAO's fisheries production database, FishStatJ. Similarly, farmed sablefish represents such a minimal amount of overall Canadian aquaculture production, that volumes of this species are not disaggregated in national production statistics and are instead aggregated into an 'other' category[7], along with other low-volume, domestically farmed finfish (Arctic char, sturgeon and tilapia (MOA 2017)), which together comprised 0.52% of national farmed production in 2017. Upon request, the DFO were able to provide specific sablefish production data, however, government policy does not permit the dissemination of farm-specific production statistics. DFO data, taken together with production data supplied by the current industry, are considered to be accurate, thus the Data score for Industry and Production Statistics is 10 out of 10.

Management and Regulations

The website of the department of Fisheries and Oceans Canada (DFO), which is the primary federal government agency responsible for overseeing the licensing, regulation and monitoring of aquaculture activities in Canada, is an easily accessible resource which clearly explains the regulatory framework that is of relevance to domestic sablefish farming. Additional information pertaining to provincial regulation of the sector is available on the website of the government of British Columbia. Further useful data are included on the Canadian Aquaculture Industry Alliance's website. These data resources allow for a comprehensive overview of the management and regulations that govern the sector at both the federal and provincial levels. The data score for Management and Regulations is 10 out of 10.

Criterion 2: Effluent & Criterion 3: Habitat

Housed under the Fisheries Act, the principle legislative instruments that govern the sector, namely the Fishery (General) Regulations (FGR), the Pacific Aquaculture Regulations (PAR) and the Aquaculture Activities Regulations (AAR), are described in detail on the DFO website. Of particular relevance to informing these two assessment criteria are the AAR guidance document: Program Protocols for Marine Finfish Environmental Monitoring in British Columbia, as well as the DFO's Aquaculture Monitoring Standard. The DFO's most recent annual report on the performance of the aquaculture sector, Regulating and Monitoring British Columbia's Marine Finfish Aquaculture Facilities, was also a useful source of information. As this

[7] http://www.dfo-mpo.gc.ca/stats/aqua/aqua17-eng.htm

assessment is based on the practices of an individual company, the co-operation of the farm owner was essential in order to secure farm-level data relevant to the preparation of sections C2 and C3. Although these farm-level data are not, by their nature, independently verified, much of the data relevant to these two criteria were prepared by third-party biologists and surveyors and as such are considered to be impartial and accurate. A number of relevant, peer-reviewed papers were also identified, particularly Brager et al. (2015), which studied suspended particulate waste in the near-field and distant-field water column of a sablefish farm in a comparable location to the farm under consideration. Other peer-reviewed titles, such as Price et al. (2015), which provided a global overview of the impact of net pen nutrient wastes arising from marine aquaculture facilities, were also useful, as were data obtained from a number of studies pertaining to salmon farming in BC; while these data were not specific to BC sablefish aquaculture, with due and careful consideration, they never the less provided some valuable insights that helped inform these two criteria. The data score for both Criterion 2: Effluents and Criterion 3: Habitat is 7.5 out of 10.

Criterion 4: Chemical Use
Due to the limited size of the sablefish aquaculture sector, and the fact that there is only one commercial net pen producer of this species at the present time, data to inform this Criterion was primarily based on DFO data (submitted by the industry and subject to audit), which was reviewed in tandem with personal communications and farm-level data provided by the operating company. The DFO website provides a comprehensive overview of the governance framework surrounding the aquaculture sector's use of chemicals. Marine farms in BC are required to report their drug usage to DFO, who in turn collate and publish these data on their website; at the time of writing, data for 2016 and 2017 is available online. To ensure the accuracy of such reporting, and to verify that all aspects of chemical management are in order, the DFO conduct random farm audits from time to time. As a result, reviewer confidence in the accuracy of the data used to assess this Criterion is moderately-high and the data score for Criterion 4: Chemical Use is 7.5 out of 10.

Criterion 5: Feed
Since there is presently just one global, commercial net pen producer of sablefish, data to inform this Criterion were provided in confidence by their feed supplier; the precise aquafeed formulation was not forthcoming, due to the understandably proprietary nature of such information. The economic FCR supplied by the company is 1.45, which is aligned with data otherwise identified in the somewhat limited amount of scientific literature concerning sablefish nutrition. Although there were not a great deal of data available to inform this Criterion, and given the inability for data to be further verified, those data that were available were considered to be moderate in quality and reliability, thus the data score for Criterion 5: Feed is 5 out of 10.

Criterion 6: Escapes
Since the sablefish farming sector is very small, there were limited data available to inform this Criterion with respect to quantifying escapes, asides from self-reported data received directly from the operating company, which attests that they have never experienced any escape

events. The governance framework pertaining to escape prevention and management of the marine farming sector in BC is available on the DFO website, as is public disclosure of reported escape events, which notably do not include any incidents of farmed sablefish escapes in any of the available annual records, which date back to 2010. Data on wild sablefish genetics were also identified and, although these data were not abundant, they were considered to be of moderate quality and adequate to inform this Criterion, given the limited domestication of farm stock and ensuing limited potential competitive and genetic risks. The data score for Criterion 6: Escapes is 5 out of 10.

Criterion 7: Diseases
BC marine farm license conditions, pertaining to biosecurity and disease management, were readily accessible on DFO's website, thus details of the regulatory aspects pertaining to this Criterion were readily identified and simple to understand. However, given the limited size of the farmed sablefish sector, few species-specific industry data were available to inform this Criterion. In addition to self-reported data provided by the operating company, including, mortality by category statistics, a small number of peer-reviewed papers were identified that included the results of disease challenge studies conducted with sablefish. These research papers were helpful in providing an insight into the pathogenic susceptibilities of this species. The data score for Criterion 7: Diseases is 5 out of 10.

Criterion 8X: Source of Stock – Independence from Wild Fisheries
Since the sablefish aquaculture sector is in its formative stages of development, hatchery technology has not yet advanced sufficiently to allow zero reliance on wild fisheries, although all juveniles stocked by the sector are domestically produced. It was easy to ascertain this current status of hatchery technology, both through personal communications with the operating company themselves, and also through peer-reviewed and grey literature available on the topic. Further to this, the status of the wild fishery, upon which the sector is still largely reliant for broodstock, is verifiably of minimal concern, as per Seafood Watch wild fisheries assessments. However, the degree to which the industry relies on wild caught broodstock could not be independently verified. Thus, the data score for Criterion 8: Source of Stock is 7.5 out of 10.

Criterion 9X: Wildlife and Predator Mortalities
Self-reported company data available on DFO's website concerning wildlife and predator interactions with marine farms in BC, particularly data that specifically quantified marine mammal deaths and the incidental capture of wild fish stocks by the aquaculture sector, were of great assistance in informing this Criterion. The DFO website also clearly explains the regulatory provisions and requirements surrounding this aspect of aquaculture production in BC. Specific data pertaining to the operating company's predator management plan, their historical reports lodged with DFO, plus details of their particular experiences with predators, were also most informative and helped provide a reliable picture of wildlife and predator mortalities pertaining to their farming activities. The data score for Criterion 9X – Wildlife and Predator Mortalities is 7.5 out of 10.

Criterion 10X: Escape of Secondary Species

The production of farmed sablefish in BC is 100% reliant on hatchery raised juveniles that are produced using locally wild-caught broodstock, which are supplemented to some degree with domestically raised F1 broodstock. The operating company's production is therefore not considered to present a risk with regards to the unintentional trans-waterbody shipment of non-native species, and the data score for this Criterion 10X: Escape of Secondary Species is 10 out of 10.

Conclusions and Final Score

Since this assessment pertains to the production of a single company, a great deal of the data used was provided directly by the farm itself; these data were generally not subject to independent verification. The operating company provided these data via personal communications as well as through provision of requisite farm reports filed with the government, which are part of DFO's licensing requirements for all marine farms in BC. These documents are evidently subject to review by DFO, who also periodically conduct random site audits to verify the accuracy of reported data. Sablefish is an emergent aquaculture sector, thus there is not a great deal of peer reviewed data available pertaining to culture of this species, however, the material that was identified was considered to be robust and of a high quality. Overall, three data categories scored 10 out of 10 (Industry and Production Statistics, Management and Regulations, and Escape of Secondary Species), five data categories scored 7.5 out of 10 (Effluent, Habitat, Chemical Use, Source of Stock, and Wildlife and Predator Mortalities), whereas three data categories scored 5 out of 10 (Feed, Escapes, and Disease). When all of these are taken into consideration, the final score for Criterion 1 – Data is 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 <u>beyond the farm or its allowable zone of effect.</u>
- 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)	**8**	**GREEN**

Brief Summary

The environmental fate of fish farm effluents has been well-studied in many parts of the world and it has been demonstrated that effective site selection does much to mitigate negative impacts caused by the dispersal of such wastes. The primary government agency responsible for overseeing the licensing, regulation and monitoring of aquaculture activities in the Province of BC is the department of Fisheries and Oceans Canada (DFO). Part of the DFO's regulatory requirements for fish farms is that benthic monitoring is regularly conducted and reported upon; farms generally hire an independent contractor to perform this work and the DFO may subsequently conduct audits to verify these results. Although these benthic surveys are of particular relevance to the Habitat Criterion, they are also relevant to this Effluent Criterion since they incorporate data collection that extends significantly beyond the farm boundary, up to a distance of 140 m. A review of the operating company's biennial monitoring survey reports demonstrate that they have always remained well within the government's compliance criteria. There is, however, no equivalent regulatory requirement for monitoring effluents in the water column. Since sablefish farming is not a well-developed industry, there is not a great deal of peer-reviewed data available specific to the sector; however, one BC sablefish farm study was identified, which analysed suspended particulate wastes in the water column. This study found that while suspended particulate wastes were detectable between depths of 1 - 3 m within the cage during feeding, no such waste signal was detected outside the cage structure: the area included in the analysis extended out to a distance of 500 m and down to a depth of 25 m. This finding aligns with a large body of literature regarding the potential effluent impacts of marine finfish aquaculture, salmon in particular, in net pens globally. In light of the operating company's low production volumes, their ongoing regulatory compliance with monitoring surveys, and the fact that there are no other operational farms within a 3 km radius, the farm's activities are not considered to contribute to local and regional nutrient loads. The final score for Criterion 2 – Effluent is 8 out of 10.

Justification of Rating
This Criterion applies to effluent effects outside the farm boundary or beyond an allowable zone of effect (AZE); with reference to net pen aquaculture, the Seafood Watch Aquaculture Standard suggests an AZE of 30 m. This Effluent Criterion (C2) therefore considers both benthic and water column impacts that occur at a distance of 30 m or more from the cage edge, whereas impacts within the farm's boundary (i.e. below the cage and within the AZE) are addressed in the Habitat Criterion (C3). Although the impact locations considered by C2 and C3 are distinct, there is a great deal of overlap in the data and research which inform these two criteria, such that some information will inevitably be of relevance to both.

Evidence-Based Assessment:
As effluent data quality and availability is good (i.e. a Criterion 1 score of 7.5 out of 10 for the effluent category), the Evidence-based assessment was utilized.

The organic wastes, nutrients and chemicals, which are generated as a by-product of farming fish in open net pens, inevitably flow unimpeded from the culture zone into the surrounding environment. These wastes primarily include fish feces and uneaten food, which are dispersed as solid particles, alongside dissolved nutrients (primarily nitrogen and phosphorus), which are released from the gills and also from the urine of fish. The environmental fate of fish farm wastes has been well-studied in many parts of the world and it has been demonstrated that effective site selection does much to mitigate negative impacts caused by the dispersal of such wastes. Research indicates that the greater the intensity of aquaculture in a region, and the shallower and less dynamic the flow of water is around cage installations, the greater the potential for negative environmental impacts (Price et al. 2015, Martinez-Porchas & Martinez-Cordova 2012). A recent study by Price et al. (2015), which collected and reviewed over 180 studies that explored the ecological impacts of marine fish farms around the world, concluded that the adoption of modern management practices has done much to minimize the negative impacts that cage farms can have on surrounding water quality parameters. The study notes that negative impacts on dissolved oxygen levels and water turbidity can largely be avoided by adherence to best management practices, such as using formulated diets and stopping the application of feed as soon as fish stop eating, and by siting farms in locations with adequate depth and current profiles. The authors comment that nutrient enrichment is typically not detectable beyond 100 meters from farms when good practices, such as these, are followed. With this in mind, it is pertinent to note that the mean annual, semi-diurnal tidal range in the locality of currently operating sablefish sites in British Columbia is approximately 3 m (Weldrick & Jelinski 2016), with corresponding depth profiles in the 70 – 115 m range and moderate current velocities between 3-5cm/second typically experienced. Mooring of cages in these relatively deep sites is accomplished using rock pins and steel high hold anchors and the nets extend down to around 30 m.

Since 2010, the primary government agency responsible for overseeing the licensing, regulation and monitoring of aquaculture activities in the Province of BC is the department of Fisheries and Oceans Canada (DFO). Housed under the Fisheries Act[8], the main legislative instruments employed by DFO to govern the sector are the Fishery (General) Regulations (FGR)[9], the Pacific Aquaculture Regulations (PAR)[10], and the Aquaculture Activities Regulations (AAR)[11] (DFO 2016). The DFO's platform of governance is the BC Aquaculture Regulatory Program (BCARP)[12], through which site inspections, surveys and audits are conducted, as well as reviews of producer's record-keeping and operational protocols (DFO 2017). As part of this procedure, farms are required to comply with scheduled and event-based reporting. Benthic monitoring and the subsequent submission of monitoring survey reports is one such mandatory, scheduled requirement for BC aquaculture facilities that produce more than 2.5 MT annually; there is, however, no equivalent compulsory requirement for monitoring water column parameters (Day et al. 2015). Although it is evident that dissolved nutrients emanating from farms are not routinely measured (if at all), the results obtained from benthic monitoring survey reports are still relevant to this Effluent Criterion, since the detailed sampling requirements defined by DFO incorporate a zone that extends considerably beyond the limits of the AZA (i.e. beyond 30 m from the edge of the cage, which is the zone applicable for consideration in this criterion).

To facilitate preparation of this assessment, the primary operating sablefish farm has provided copies of their biennial monitoring survey reports for both farm sites. These reports, which date back to 2013, were compiled by a third-party independent surveyor, in accordance with the DFO's Aquaculture Activities Regulations (AAR) guidance document: Program Protocols for Marine Finfish Environmental Monitoring in British Columbia[13].

The AAR guidance protocol stipulates the timing and frequency of 'peak biomass' monitoring as follows:

- Within 30 days either side of peak biomass for farms that have a production cycle ending in the complete removal of all fish; or
- At the end of every 24 month period if the production cycle is longer than 24 months; or
- Every 24 months for brood stock farms and/or with finfish continuously on site.

The last bullet point indicates the AAR strategy applicable to the current industry configuration; since fish are reportedly continuously on site[14] at the operating farm, benthic monitoring of both sites is required every two years. As further outlined in the AAR guidelines, the monitoring procedure employed is dependent upon the substrate over which the farm is sited: direct sediment sampling is used for soft ocean substrates, whereas video, collected by ROV (remotely operated vehicle), is used to assay hard bottoms. In the case of these two sites, a combination of both survey methods is required, since the sites exhibit a combination of both hard and soft

[8] https://laws-lois.justice.gc.ca/eng/acts/F-14/
[9] https://laws-lois.justice.gc.ca/eng/regulations/SOR-93-53/
[10] https://laws-lois.justice.gc.ca/eng/regulations/SOR-2010-270/
[11] https://laws.justice.gc.ca/eng/regulations/SOR-2015-177/page-1.html#h-820176
[12] http://www.dfo-mpo.gc.ca/aquaculture/bc-aquaculture-cb-eng.html
[13] http://www.dfo-mpo.gc.ca/aquaculture/management-gestion/aar-raa-gd-eng.htm#annex8.2
[14] Except during fallowing periods, which is explored in more detail in the Habitat Criterion

substrates. The satellite image presented in Figure 3 shows the location of the two on-growing sites.

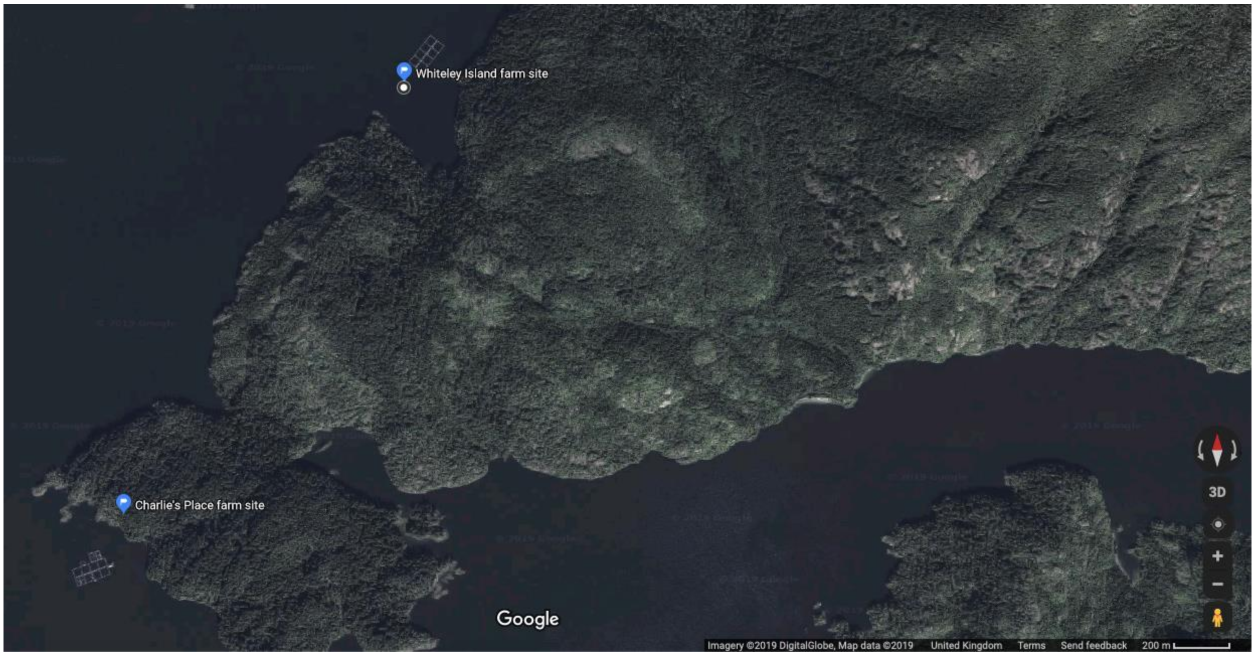

Figure 3: Satellite image showing the cage array placement at two on-growing sites in Kyuquot Sound, Vancouver Island, BC: Whiteley Island site (above) and Charlie's Place site (below). Note that the legend indicates a relative scale of 200 meters (Imagery © 2019 DigitalGlobe, Map data © 2019 Google)

Further instructions for monitoring are provided in the DFO's Aquaculture Monitoring Standard[15], which details how sampling transects should be determined dependent on the specific characteristics of the site. The overarching aim of such monitoring is to ensure that benthic impacts are fully reversible if the site is left fallow, and this is primarily determined by either measuring the concentration of free sulfides (S^{2-}) in sediment samples taken from soft substrates or by visually determining the extent of organic enrichment by quantifying *Beggiatoa*-like species, which form bacterial mats, and marine worms (opportunistic polychaete complexes, OPC) in hard substrates - the latter of which is facilitated through video surveys. Free sulfides, which are produced by bacteria during anaerobic decomposition of organic material have been shown to correspond with a reduction in ecological diversity when levels are elevated, whereas filamentous *Beggiatoa*-like species and OPCs are indicative of high organic enrichment; both parameters have thus been deemed to be appropriate proxies for measuring benthic biodiversity impacts and are suitable indicators for establishing performance thresholds.

The DFO Monitoring Standard notes that for visual monitoring: "*In the case of an aquaculture facility that is located in tidal waters in or adjacent to British Columbia, images must be*

[15] http://www.dfo-mpo.gc.ca/aquaculture/management-gestion/doc/AAR-Monitoring-Standard-2018-eng.pdf

recorded along two transects that start at the edge of the proposed containment array, align with the area of greatest predicted impact and with the dominant and sub-dominant current directions and extend for a minimum of 140 m," and similarly, for soft substrate monitoring the Standard states that *"[in] British Columbia, collect samples of the benthic substrate at a minimum of two sampling stations (30 m and 125 m away from the cage edge) along two transects that align with the area of greatest predicted impact and with the dominant and sub-dominant current directions".*

To meet the requirements of the AAR, free sulfide concentrations calculated at a distance of 30 meters from the cage structure must not be greater than 1,300 micro molar (µM) and at 125 meters distance must not exceed 700 µM (DFO 2019a). To be compliant with AAR hard bottom visual monitoring requirements, in which video footage is recorded in six separate segments (each comprising four meters) between 100 m and 124 m, *Beggiatoa*-like species and OPCs must not be evident in 10% or more of any four segments of substrate. A review of the operating industry's monitoring reports, dating back to 2013, indicate that both sites have remained well within the AAR compliance requirements with regards to both soft and hard bottom transect monitoring.

While there is not a great deal of peer-reviewed data available that pertains specifically to the effluent impacts of sablefish farming specifically, one relevant study was identified (Brager et al. 2015). The authors of this study analysed the spatial distribution of suspended particulate wastes generated by a number of marine farms in Canada, including a sablefish farm in Kyuquot Sound. The study was conducted in 2011, during which time the farm was reportedly holding 100,000 harvest-sized sablefish on site, in addition to a small quantity of scallops and kelp. The site depth was recorded as being approximately 28 m and the tidal range as 3 m. The profile of suspended particulate wastes incurred by the application of feed at the farm was measured using an array of instruments, which facilitated an in-depth analysis at varying depths and distances from the cage installation. Data were collected inside the cage before, during and after feeding, incorporating measurements taken from the surface down to 15 m. In addition, upper water column tows collected data from within 5 m of the cage installation out to a distance of 500 m, taking measurements between the water surface down to a depth of 10 m. To incorporate profiling down to a depth of 25 m, transect studies were also undertaken.

Authors of the study noted that there are many site-specific characteristics which influence the dynamics of fish farm wastes, including the farm structure itself and the behavioural traits of the species being cultured. Sablefish, the authors note, ascend to feed but otherwise tend to congregate toward the bottom of the net pen, as a result of this their feces generally enter the water column lower down and do not impact surface waters. The data collected inside cages indicated that fine particulate matter was released at depths of 1 − 3 m during feeding, although authors noted that this evident enhancement of total suspended particulate matter (TPM) was within the range of natural variation noted in measurements taken prior to feeding. In conclusion, the researchers stated that "*Within-pen sampling at a sablefish Anoplopoma fimbria farm in British Columbia provided some evidence of the release of low levels (mean* *effect <0.2 mg l−1) of waste feed near the surface (1−3 m depth), but no waste signal was detectable in surface waters outside this farm*" (Brager et al. 2015).

One further aspect that this Effluent Criterion takes into account is the potential cumulative effects that can arise from the combined discharge of groups of farms in the same vicinity, which can contribute to regional nutrient loading. The DFO's siting guidelines for marine farms in BC indirectly addresses this concern by stating that "*Aquaculture facilities should be located at least three kilometres from an existing marine finfish facility or operate under co-ordinated Health Management Plans*"[16]. A review of DFO's licensed BC marine finfish aquaculture facilities map[17] shows another finfish farm site in close proximity (i.e. less than 3 km away) to the two currently operating sites. This site is evidently still licensed to the company from whom the operating company acquired their two sites, but it has remained fallow since the mid-2000s and there are reportedly no plans to resume operations (pers. comm. Bernie John Taekema, DFO August 2019).

In conclusion, data show no evidence that effluent discharges from sablefish farms in British Columbia cause or contribute to cumulative impacts at the waterbody scale. The final score for Criterion 2 – Effluent is 8 out of 10.

Conclusions and Final Score

Part of the DFO's regulatory requirements for fish farms is that benthic monitoring is regularly conducted and reported upon. Although these benthic surveys are of particular relevance to the Habitat Criterion, they are also relevant to this Effluent Criterion, which considers both benthic and water column impacts that occur at a distance of 30 m and farther from the cage edge. DFO benthic survey reports incorporate data collection that extends significantly beyond the farm boundary (AZE), up to a distance of 140 m. A review of biennial monitoring survey reports demonstrate that the currently operating sites in the industry have always remained well within the government's compliance criteria. Although there is no equivalent regulatory requirement for monitoring effluents in the water column, a BC sablefish farm study which measured suspended particulate wastes in the water column did not detect such wastes beyond the confines of the cage, even during feeding. In light of current low production volumes, ongoing regulatory compliance with monitoring surveys and the fact that there are no other farms operating within a 3 km radius beyond the two active sites, the BC sablefish industry is not considered to cause or contribute to local or regional nutrient loads. The final score for Criterion 2 – Effluent is 8 out of 10.

[16] https://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/site-guide-direct-eng.html
[17] http://www.dfo-mpo.gc.ca/aquaculture/bc-cb/docs/maps-cartes/mar-eng.pdf

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 on 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			7
F3.2a Content of habitat regulations		3	
F3.2b Enforcement of habitat regulations		4	
F3.2 Regulatory or management effectiveness score			5
C3 Habitat Final Score (0-10)			**6**
	Critical?	NO	**YELLOW**

Brief Summary

Aquaculture cage installations typically do not cause direct habitat impacts. However, if fish feces and uneaten food are not adequately dispersed, and subsequently accumulate on the benthos under and around the net pen, they can have significant, measurable habitat impacts. With regard to the potential environmental impacts of marine farms in BC and their regulation, the content of habitat management measures that are in place at the farm-level are considered to be robust and regulation of the sector is based on maintaining ecosystem functionality of the habitats in which fish farms are sited. These management measures require that farms perform benthic monitoring and report these data to the DFO on an ongoing, scheduled basis; if performance thresholds are breached, sites must be fallowed until benthic remediation has been effected. According to data provided by the operating company, the functionality of the benthic habitats located within the AZEs of their two farm sites are considered to be maintained, exhibiting only minor impacts – although the last DFO audit performed to verify the company's status in this regard took place in 2014. While governance at the farm-level appears to be robust, management and enforcement measures to explicitly address cumulative industry impacts at the regional-level in BC is evidently limited. This results in a final Criterion 3 – Habitat score of 6.27 out of 10.

Justification of Rating

In contrast to the Effluent Criterion (C2), this Habitat Criterion (C3) applies to the environmental impacts that fish farming activities may have *inside* the farm boundary, i.e. within an allowable zone of effect (AZE). With reference to net pen aquaculture, the Seafood Watch Aquaculture Standard suggests an AZE of 30 m, unless otherwise specified in regulations. This Criterion therefore considers impacts that occur in, below and around the operating company's net pens and extending out to a distance of 30 m from the cage edge. As noted in C2, although the impact locations considered by C2 and C3 are distinct, there is a great deal of overlap in the data and research which inform both criteria because the source of the impact, primarily fish feces and uneaten food, is the same. Note that governance of sablefish culture in BC largely parallels that which is applicable to the BC Atlantic salmon sector, thus some of the following text is adapted from the Seafood Watch assessment of BC farmed Atlantic salmon (Seafood Watch 2017).

Factor 3.1. Habitat conversion and function
Intensive fish farming activities generate a localized gradient of organic enrichment in the underlying and adjacent sediments as a result of settling particulate wastes (primarily feces) and can strongly influence the abundance and diversity of infaunal communities. In the area under the net pens or within the regulatory AZE, the impacts may be profound, but are now relatively well understood (Keeley et al. 2015, Keeley et al. 2013, Backman et al. 2009, Black et al. 2008). Primarily, changes can be anticipated in total volatile solids, redox potential, and sulfur chemistry in the sediments in the immediate vicinity of operational net pens, along with changes to the species composition, total taxa, abundance, and total biomass (Keeley et al. 2013). Significant decreases in both the abundance and diversity of macrofauna are sometimes seen under farms located in depositional areas, characterized by slow currents and fine-grained sediments, while net pens located in erosional environments with fast currents and sediments dominated by rock, cobble, gravel, and shell hash can dramatically increase macrobenthic production (Keeley et al. 2013).

As discussed in Criterion 2 – DFO use a range of tools to manage and regulate such potential benthic impacts, one of which is the mandatory benthic surveys that fish farms must conduct on an ongoing basis. BC's currently active sablefish sites, which exhibit a combination of both hard and soft substrates, have been located on the same tenures since 2005 (prior to this they had been used as salmon sites) and they have reportedly never failed to meet DFO's regulatory restocking parameters (pers. comm. Don Read, GESF, May 2018). In addition to the currently operating company providing their biennial monitoring survey reports to inform this Criterion, DFO's benthic audit survey results from 2011 to 2017 are available publicly on the DFO website[18], and indicate that the company was audited in 2014. The comments pertaining to this audit state that the operating company have: "*No peak biomass date since fish [are] cultivated continuously at the facility; there is agreement between DFO and industry results*" and that "*All sediment sampling stations had acceptable levels of chemical impact; All transect videos showed acceptable levels of visual indicators of impact*".

It is now a globally common practice for farm sites to be fallowed between production cycles for a variety of reasons, including benthic management and for pathogen control, however, the

[18] https://open.canada.ca/data/en/dataset/c1a54a0c-4eb0-4b50-be1f-01aee632527e

DFO's Aquaculture Activities Regulations (AAR) guidance document: Program Protocols for Marine Finfish Environmental Monitoring in British Columbia[19] does not mandate a fallow period in BC. Instead, all sites must be shown to be under the regulatory performance thresholds before restocking. Since sablefish farming is an emergent sector, long-term studies on fallowing and benthic remediation pertaining to this species are not evident; however, such interactions have been well-studied with regard to salmon farming in the Pacific Northwest. According to Brooks and Mahnken (2003), chemical and biological remediation in BC has been shown to occur naturally during fallow periods at every salmon farm studied, but Keeley et al. (2015) showed that, although significant recovery was evident at the fallowed site in the first six months, full recovery is often not completed before restocking occurs. This can create a complex "boom and bust" cycle of opportunistic taxa as one production cycle ceases (at harvest) and is then re-established (at restocking). For full recovery, Keeley et al. (2015) and references show that estimates vary between 6 months and 5 years or more, and are highly specific to the environment and the situation. In this regard, it should be noted that BC's current, solo commercial net pen producer of sablefish implements routine fallowing of sites for 3 months every 24 months, as part of the company's standard operational procedures (pers. comm, Claire Li, GESF, May 2019), and has continually remained in compliance with DFO's regulatory benthic monitoring thresholds.

Some have raised concerns about the biological impact that copper and zinc may have on organisms within the footprint of marine farms (Burridge et al. 2010); the former of these metals is often used in net antifouling preparations and the latter is frequently found in fish feed. Although monitoring of these metals is not a mandatory regulatory requirement in BC at the present time, the operating company has frequently elected to include monitoring data for these metals in the biennial benthic survey reports that they prepare for DFO. Since the company do not use antifoulants (pers. comm, Claire Li, GESF, May 2019), there is no potential for habitat impacts arising from the use of copper-based antifoulants at either of the operating company's sites. Although the feeds used by the company do incorporate zinc as a mineral supplement, the low stocking densities employed indicate that zinc accumulation in the benthos is unlikely, and monitoring results indicate that accumulation is not occurring. Based on the above, the functionality of the benthic habitats located within the AZEs of the company's two farm sites are considered to be maintained, exhibiting only minor impacts; however, while impacts may be relatively quickly reversible by reducing the load, fallowing, or removing the farm, long production periods with short fallow periods may maintain impacts for long periods. Thus, thus the score for Factor 3.1 – Habitat Conversion and Function is 7 out of 10.

Factor 3.2. Farm siting regulation and management

Scoring for Factor 3.2 is subdivided into Factor 3.2a (content of habitat management measures) and Factor 3.2b (enforcement of habitat management measures).

[19] http://www.dfo-mpo.gc.ca/aquaculture/management-gestion/aar-raa-gd-eng.htm#annex8.2

Factor 3.2a: Content of habitat management measures

As can be noted in Figure 4, new aquaculture sites require the approval of both federal and provincial agencies. A review of the development of Canadian aquaculture governance in recent years demonstrates that it is a dynamic process and continues to evolve in tandem with sector expansion; with this in mind, it is interesting to note that a new Federal Aquaculture Act is currently in development (DFO 2019c). This proposed act, which would be the country's first aquaculture-specific piece of legislation, could potentially be enacted in early 2022[20].

	British Columbia
Site Approval Determining where a farm can be located	Shared
Land Management Overseeing the land (seabed) where a farm is located	Provincial
Day to Day Operations & Oversight Monitoring of farm activities	Federal
Introductions & Transfers Managing the planned movement of live eggs and fish	Shared
Drugs & Pesticide Approvals Determining which drugs and pesticides are approved for use	Shared
Food Safety Monitoring and ensuring the safety and quality of fish harvested and sold in Canada and international markets.	Federal

Figure 4: A snapshot of the aquaculture regulatory framework in British Columbia showing the division between Federal and Provincial responsibilities (DFO 2019c)

As previously discussed in the Effluent Criterion, since 2010, the primary federal agency responsible for aquaculture governance throughout Canada is the DFO; the principle legal instrument that supports implementation of this task is the Fisheries Act. Under the authority of the Fisheries Act, there are three main regulations that facilitate the application and enforcement of the Act: the Fishery (General) Regulations (FGR)[21]; the Pacific Aquaculture Regulations (PAR)[22]; and the Aquaculture Activities Regulations (AAR)[23]. Together, these legal provisions support the licensing, regulation and monitoring of aquaculture activities across Canada. In the Province of BC, these activities are administered through the BC Aquaculture Regulatory Program (BCARP)[24], which conducts site inspections, surveys and audits, as well as reviews of producer's record-keeping and operational protocols (DFO 2017). As part of this procedure, farms are required to comply with scheduled and event-based reporting. Benthic monitoring and the subsequent submission of monitoring survey reports is one such mandatory, scheduled requirement for BC aquaculture facilities that produce more than 2.5 MT annually. The DFO website states that: "*The benthic monitoring program is designed to limit the location, area, and intensity of impact created by fish farms to the seabed and to support sustainable aquaculture by maintaining healthy ecosystems*"[25]. Complete details of these monitoring requirements are provided in DFO's Aquaculture Activities Regulations (AAR) guidance document: Program Protocols for Marine Finfish Environmental Monitoring in British Columbia[26]. Essentially, the AAR assesses benthic habitat impacts by monitoring sulfide

[20] https://www.aquaculturenorthamerica.com/canadas-proposed-aquaculture-act-coming-in-2022-2344/
[21] https://laws-lois.justice.gc.ca/eng/regulations/SOR-93-53/
[22] https://laws-lois.justice.gc.ca/eng/regulations/SOR-2010-270/
[23] https://laws.justice.gc.ca/eng/regulations/SOR-2015-177/page-1.html#h-820176
[24] http://www.dfo-mpo.gc.ca/aquaculture/bc-aquaculture-cb-eng.html
[25] https://open.canada.ca/data/en/dataset/c1a54a0c-4eb0-4b50-be1f-01aee632527e
[26] http://www.dfo-mpo.gc.ca/aquaculture/management-gestion/aar-raa-gd-eng.htm#annex8.2

concentrations in sediment samples, but when a sediment sample is not obtainable, due to the bottom substrate being hard, a visual assay is performed using the presence and abundance of *Beggiatoa* species (or similar bacteria) or marine worms (e.g. class *polychaeta*) as biomarkers to indicate benthic impacts. These marine worms actually help to break down organic depositions, but their abundance is indicative of excessive organic enrichment (DFO 2017).

In addition to the continuous monitoring and assessment of aquaculture habitat impacts that the AAR mandates, another key measure employed to manage potential habitat impacts is the implementation of siting criteria for new aquaculture installations, which are included in the DFO's siting guidelines for marine finfish aquaculture[27]. One aspect of siting regulations where management measures appear to be limited pertains to cumulative industry impacts. Although the aforementioned siting guidelines state that: "*Aquaculture facilities should be located at least three kilometres from an existing marine finfish facility or operate under co-ordinated Health Management Plans*," it is evident that in practice this provision is only applicable to the Atlantic salmon sector, where it is implemented as a biosecurity measure, intended to reduce the disease transfer risks associated with this industry - rather than as an area-based regulation designed to mitigate cumulative industry impacts. It is apparent that other types of aquaculture facilities in BC are not required to be at least 3 km apart, as is evident with the BC chinook sector (MBA 2019), thus this provision cannot be interpreted as an area-based regulation.

Regulation of the BC sablefish sector is based on maintaining ecosystem functionality in the habitats affected, and the content of habitat management measures applicable to the industry are based on ecologically sound principles. However, since consideration of cumulative industry impacts is lacking, the regulatory system is considered overall to be moderately robust. The score for Factor 3.2a is 3 out of 5.

Factor 3.2b: Enforcement of habitat management measures

The DFO's last benthic audit of the operating company took place in 2014; the results of this, as well as benthic audit results for all other BC marine farm sites, are archived and updated (temporal coverage is to 12/31/2018 at the time of writing) and made available on DFO's website[28].

The DFO's 2017 report on regulation and monitoring of BC's marine finfish sector states that all sites must be demonstrably compliant with the thresholds before restocking: "*The standards for free sulphides are designed to manage the intensity of impact and ensure that the seabed can recover in a reasonable amount of time when fish are removed from marine net pens. When thresholds of free sulphides at the 30 metre and 125 metre stations are exceeded, the site must be fallowed (no fish) until further monitoring shows that it has recovered sufficiently*". Likewise,

[27] http://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/site-guide-direct-eng.html
[28] https://open.canada.ca/data/en/dataset/c1a54a0c-4eb0-4b50-be1f-01aee632527e

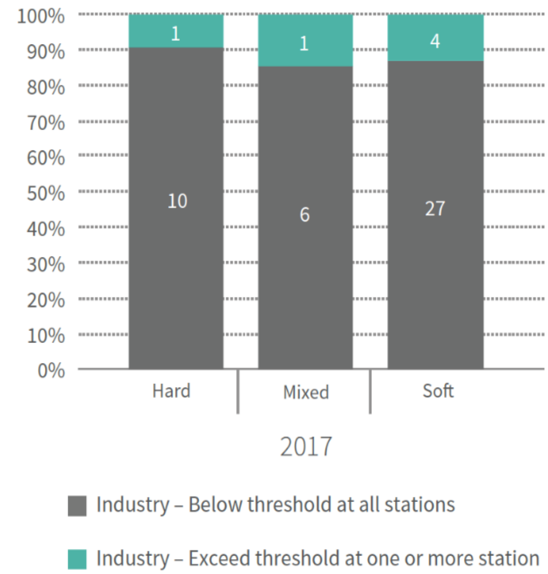

Figure 5: BC Aquaculture Industry-Reported Benthic Monitoring Events, 2017 (DFO 2017)

"The zone of compliance for hard bottom sites is between 100 and 124 metres from the cage array, although video is always also taken closer and farther away," (DFO 2017). Figure 5 shows a summary of the aquaculture sector's (dominated by Atlantic salmon production) compliance with benthic monitoring thresholds, as per reports submitted by the aquaculture sector to DFO between January and September 2017; these data indicate that 82% of the 39 facilities sampled during this timeframe were within the allowable environmental thresholds.

In the event that farm operators are found to be in breach of their license criteria, the DFO has the authority to enforce prosecution. The DFO makes its compliance findings publicly available (FFE 2015) on the department's website and also produces the aforementioned annual report. The most recent report, Regulating and Monitoring British Columbia's Marine Finfish Aquaculture Facilities 2017, (DFO 2017), which gives an overview of the sector's regulatory performance with regards to the Pacific Aquaculture Regulations and the Aquaculture Activities Regulations, states that *"There were no charges or convictions related to marine finfish operations in 2017*".

A review of the enforcement of habitat management measures indicates that the regulatory system is effective, with minor limitations given that not all facilities that fail to meet the thresholds will be subjected to timely audits. In BC, active enforcement organizations are easily identifiable and contactable, their resources are appropriate to the scale of the industry, and evidence of penalties for infringements are available. Additionally, the permitting or licensing process is transparent and easily understood. The score for Factor 3.2b is 4 out of 5. When combined with the Factor 3.2a score of 3 out of 5, the final Factor 3.2 score is 4.8 out of 10.

Conclusions and Final Score

The benthic habitats located within the AZEs of BC's two currently operating sablefish farm sites are considered to be maintaining functionality, exhibiting only minor impacts, which results in a score of 7 out of 10 for the habitat conversion and function score (Factor 3.1). The final score for this Habitat Criterion combines the Factor 3.1 score along with the scores for the content and enforcement of habitat management measures (Factors 3.2a and 3.2b). Overall, the content of habitat management measures (Factor 3.2a) applicable to sablefish marine net pen farms in BC would appear to be moderately robust, albeit with some limitations in regard to cumulative, regional impacts. Enforcement of these measures (Factor 3.2b) appears to be effective, with only minor limitations. Enforcement organizations are both identifiable and contactable and regulatory procedures are transparent and easily understood; audit results, including infringements, are made publicly available. Taken together, Factors 3.1 and 3.2 combine to give a final Criterion 3 – Habitat score of 6.27 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.
- Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments
- Principle: limiting the type, frequency of use, total use, or discharge of chemicals to levels representing a low risk of impact to non-target organisms.

Criterion 4 Summary

Chemical Use parameters		Score	
C4 Chemical Use Score (0-10)		**8**	
	Critical?	NO	**GREEN**

Brief Summary

Given the small size of the sablefish aquaculture industry, there is not a great deal of general data available concerning the sector's chemical usage. Most information used to inform this Criterion was therefore obtained from DFO materials and from data provided directly by the only presently active commercial net pen producer of sablefish. Farmed sablefish do not typically suffer from parasites thus parasiticides are not required during production. The main pathogen that afflicts cultured sablefish is furunculosis; bespoke sablefish vaccines to counteract this disease are in development and are reportedly becoming more effective, however, a range of government approved antibiotics have been used by the industry to combat this ailment in recent years. When used, these drugs have been administered under the direction of a veterinarian and in accordance with a federally approved fish Health Management Plan (HMP). Canadian fish farm operators are required to report their drug use to DFO, and this information is subsequently made publicly available on DFO's National Aquaculture Public Reporting web page; at the time of writing, datasets for 2016 and 2017 are assessable through this portal. The records of the farm currently in production, indicate that antibiotics have been used on a number of individual cages during some production cycles but, taken cumulatively, these data show that chemical treatments are used on average less than once per year at each site. Since these treatments are administered into open net pens, this inevitably allows their release into the environment. But, when treatments are used less than once per year, this results in a low overall concern according to the Seafood Watch Standard. In order to verify that drug usage reporting is accurate and that HMPs are being adhered to, the DFO perform site inspections and publicly report on the sector's compliance in this regard. During production, the operating company use a number of other chemicals, asides from antibiotics, which include disinfectants for routine cleaning as well as a government approved anaesthetic, none of which are considered to present an ecological risk. Overall, the available data indicate that chemical treatments are used, on average, less than once per year and this results in a score of 8 out of 10 for Criterion 4 – Evidence or Risk of Chemical Use.

Justification of Rating

For the purposes of this Criterion, the term 'chemicals' includes pesticides (parasiticides, piscicides), antibiotics, antifoulants, disinfectants, anaesthetics and herbicides. Of note, vaccines are not assessed in this Criterion as, and in accordance with the Seafood Watch Standard, their use is not considered to have an ecological impact.

Since commercial sablefish farming is a recent endeavor and production volumes thus far have been small, there is not a great deal of general data available concerning the sector's chemical usage. This Criterion is therefore mainly informed by DFO reports and confirmed by the operating company. Farmed sablefish reportedly do not suffer from external parasites, such as sea lice (pers. comm. Claire Li, GESF, May 2019, DFO 2019d; AAA 2010), thus no pesticides are needed or used. The operating company's fish stocks are monitored for internal parasites, although none have ever been detected (pers. comm. Claire Li, GESF, May 2019).

The company advise that the main pathogenic issue for sablefish is common furunculosis, caused by the Aeromonas genus of bacteria, and that no other pathogen or virus concerns have arisen (pers. comm. Claire Li, GESF, May 2019; pers. comm. Don Read, GESF, May 2018). Vaccine development for the treatment of furunculosis has been ongoing for a number of years (Goetz & Parsons 2019) and the operating company report that the efficacy of the vaccine they employ has improved, such that no antibiotics have been required to treat new fish stocked during 2018 or 2019 (pers. comm. Claire Li, GESF, September 2019).

Occasional outbreaks of furunculosis have affected batches of fish stocked prior to 2018, however, and these have been treated with veterinary prescribed antibiotics in accordance with the company's federally approved fish Health Management Plan (HMP) (pers. comm. Claire Li, GESF, May 2019). The type and quantity of these antibiotics are shown in Table 2. All of the drugs listed are included in the Government of Canada's 'List of Veterinary Drugs that are Authorized for Sale by Health Canada for Use in Food-Producing Aquatic Animals - Health Canada'[29]. There is a growing awareness that over-use of antibiotics, for both human and animal health care, presents a serious concern as it could result in antimicrobial resistance (AMR) and the proliferation of drug resistant diseases (Okocha et al. 2018); with this in mind, it is relevant to note that florfenicol, oxytetracycline and sulfadimethoxine are listed as highly important for human medicine by the World Health Organization (WHO 2017). Data on chemical usage at the operating company's sites prior to 2015 was not available.

[29] https://www.canada.ca/en/health-canada/services/drugs-health-products/veterinary-drugs/legislation-guidelines/policies/list-veterinary-drugs-that-authorized-sale-health-canada-use-food-producing-aquatic-animals.html

Table 2: Type, frequency and number of drugs administered under veterinarian supervision at the operating company's farm sites between 2015 – 2018 (site names are abbreviated to: CP-Charlie's Place and WI - Whiteley Island) – Note that CP is comprised of 12 cages in total and whereas WI is comprised of 8)

Year	Drug	Quantity (kg)	Number of Cages Treated	Number of Treatments	Treatments per site	Site
2015	Florfenicol	0.60	1	1	1/8	WI
2016	Florfenicol	4.40	5	1	7/8	WI
2016	Oxytetracycline	71.34	2	1		
2017	Oxytetracycline	18.00	1	1	1/8	WI
2017	Oxytetracycline	23.71*	4	1	4/12	CP
2018	Romet 30 (Sulfadimethoxine & Ormetoprim)	20.00	1	1	1/8	WI
2018	Romet 30 (Sulfadimethoxine & Ormetoprim)	25.65	3	1	7/12	CP
2018	Oxytetracycline	604.91**	4	1		

* Note: This quantity had previously been incorrectly reported to DFO as 127.45 kg; the operating company has subsequently followed up with DFO to amend this, in conjunction with their veterinary prescriptions for the period (pers. comm. Claire Li, GESF, March 2020).

** Note: This significant increase in quantity of antibiotic applied was due to the greater biomass (larger-sized fish) being treated on this occasion (pers. comm. Claire Li, GESF, February 2020).

These data have also been reported by the operating company to DFO, who collect and collate information on drug use across the national aquaculture sector and subsequently publish them on the DFO website; at the time of writing, data for 2016 and 2017 are available online. Submission of these data is part of the annual reporting requirements of the AAR, which in turn addresses sections 35 and 36 of the Fisheries Act[30] that pertain to fisheries protection and pollution prevention. The AAR also instructs fish farmers on the appropriate management measures which must be adhered to in the process of treating pathogens and parasites; this includes a requirement for farmers to report upon and explain the due consideration they have given to usage and application of the drug in question (DFO 2019e). All fish farms in Canada are required to develop and adhere to a federally approved fish Health Management Plan (HMP), the intent of which is to maintain the good health of fish stocks. In order to remain in good standing, aquaculture licenses are contingent upon on-farm enforcement of these plans, compliance with which is verified by the DFO during inspections, as is the accuracy of submitted AAR reports. Amongst others, a farm's HMP outlines the operating procedures that must be followed when handling and using drugs and chemicals, including the maintenance of

[30] https://laws-lois.justice.gc.ca/eng/acts/F-14/

treatment records as well as the designation of key fish health personnel (DFO 2017). At the time of writing, datasets for 2016 and 2017 are available on DFO's National Aquaculture Public Reporting web page[31].

A review of the operating company's drug usage data, as is summarized in Table 2, demonstrates that although antibiotics have been used on a number of individual cages during some production cycles, treatment of every cage within a site has never occurred within a single year; as such, the average occurrence of antibiotic treatment is less than once per year at each site in total.

The operating company have reportedly never used antifoulants, such as copper. Instead, a mechanical net cleaner is used, and cleaning typically occurs twice a year during spring and fall, in accordance with the amount of biofouling present. Disinfectants are used: these are chlorine bleach and Virkon[32], which is a multi-purpose sanitizer. Likewise, the anaesthetic tricaine methane sulfonate (TMS), also known as MS-222, is employed by the operating company to sedate fish during routine sampling and weighing. This reportedly amounts to approximately 3 kg of product being used per year, which is administered as prescribed by the farm's veterinarian and in accordance with the company's federally approved fish Health Management Plan (HMP) (pers. comm. Don Read, GESF, May 2018). Given that these disinfectants are used on surfaces and minimal volumes enter the environment, alongside the limited volumes of anaesthetics applied, the use of these chemicals is of minimal concern.

Conclusions and Final Score

The main pathogen that afflicts sablefish is furunculosis. DFO data indicate that antibiotics have been used to treat a number of cages during some production cycles but, on average, this amounts to less than one treatment per year at each site, and this was confirmed by data supplied by the operating company. Since these treatments are administered into open net pens, this inevitably allows their release into the environment, but when treatments are used less than once per year, this results in a low overall concern according to the Seafood Watch Standard. In order to verify that drug usage reporting is accurate and that fish health management plans are being adhered to, the DFO perform site inspections and publicly report on the sector's compliance in this regard. No other concerns with chemical use were identified. The final numerical score for Criterion 4 – Chemical Use is 8 out of 10.

[31] https://open.canada.ca/data/en/dataset/288b6dc4-16dc-43cc-80a4-2a45b1f93383

[32] https://www.fishersci.co.uk/webfiles/uk/web-docs/SLSGD05.PDF

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 Fish In: Fish Out ratio (FIFO)		1.07	7.32
F5.1b Source fishery sustainability score		-4.00	
F5.1: Wild fish use score			6.47
F5.2a Protein IN (kg/100kg fish harvested)		25.39	
F5.2b Protein OUT (kg/100kg fish harvested)		21.15	
F5.2: Net Protein Gain or Loss (%)		-16.69	8
F5.3: Feed Footprint (hectares)		11.73	6
C5 Feed Final Score (0-10)			**6.73**
	Critical?	NO	**GREEN**

Brief Summary

Since there is presently only one global, commercial net pen producer of sablefish, data to inform this Criterion were provided by this company's feed supplier and confirmed by information found in the literature. The economic FCR supplied by the company is 1.45, which is aligned with data otherwise identified in scientific literature. The calculated Feed Fish Efficiency Ratio (FFER) for farmed sablefish is 7.32 out of 10 and this, combined with a Sustainability of the Source of Wild Fish score of -4 out of -10, results in an overall Factor 5.1 score of 6.47 out of 10. Protein in feeds used for the company's farmed sablefish are sourced from 17.06% marine ingredients, 18.75% crop ingredients and 46.41% land animal ingredients, however, 61.94% of these protein inputs are considered to come from sources not suitable for human consumption. Extrapolated feed calculations demonstrate a net edible protein loss of 16.69%, which provides an overall score of 8 out of 10 for Factor 5.2. The calculated feed footprint for production of one MT of farmed sablefish is 11.73 hectares, which results in an overall Factor 5.3 score of 6. Taken together, Factors 5.1, 5.2 and 5.3 combine to give a final Criterion 5 – Feed score of 6.73 out of 10.

Justification of Rating

Overview of sablefish diets

Since sablefish aquaculture is not yet a well-developed industry, optimal diets for this species are still being refined. One research initiative in this regard, which was supported through the DFO's Aquaculture Collaborative Research and Development Program (ACRDP) [33], used fish from the operating company to conduct feed trials with the aim of determining the optimal nutritional profiles for growth and feed efficiency (Forster et al. 2016). Similar trials are also ongoing at NOAA's Manchester Research Station in Washington State. Although bespoke and life-stage specific diets are not yet commercially available for sablefish, research indicates that a high lipid component is an important factor for this species (Goetz & Parsons 2019). Data to inform this Feed Criterion were provided by the operating company, who obtained this information directly from their commercial feed supplier, as well as information found in the literature.

Factor 5.1 - Wild Fish Use

This Factor measures the amount of wild fish used (Factor 5.1a) to produce farmed fish, as well as the sustainability of the fisheries from which they are sourced (Factor 5.1b); taken together, these sub-factors combine to give a score from 0-10 for Factor 5.1 - Wild Fish Use.

Table 3: The parameters used and their calculated values to determine the use of wild fish in feeding farmed BC sablefish production

Parameter	**Data**
Fishmeal inclusion level	20%
Percentage of fishmeal from by-products	41%
Fishmeal yield (from wild fish)	22.5%[34]
Fish oil inclusion level	9%
Percentage of fish oil from by-products	59%
Fish oil yield	5.0%[35]
Economic Feed Conversion Ratio (eFCR)	1.45
Calculated Values	
Feed Fish Efficiency Ratio (FFER) (fishmeal)	0.76
Feed Fish Efficiency Ratio (FFER) (fish oil)	1.07
Seafood Watch FFER Score (0-10)	**7.32**

Note: Fishmeal (FM) and fish oil (FO) inclusion rates in the operating company's sablefish on-growing diet (data obtained directly by the company from their feed supplier) and average economic FCR (eFCR) realized by the operating company for harvest-sized fish in the 2.5 - 3.2 kg range (pers. comm. Claire Li, GESF, July 2019)

[33] https://www.dfo-mpo.gc.ca/aquaculture/acrdp-pcrda/info-eng.html

[34] 22.5% is a fixed value from the Seafood Watch Aquaculture Standard based on global values of the yield of fishmeal from typical forage fisheries. Yield estimated by Tacon and Metian (2008).

[35] 5% is a fixed value from the Seafood Watch Aquaculture Standard based on global values of the yield of fish oil from typical forage fisheries. Yield estimated by Tacon and Metian (2008).

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)[36]
Dependency on wild fisheries is measured by considering the quantity of wild fish used in feed in comparison to the harvested volume of farmed fish produced. As shown in Table 3, and as per the advice of the company's feed supplier, the sablefish on-growing diet in use features inclusion rates of 20% fishmeal and 9% fish oil. Of this, 41% of fishmeal and 59% of fish oil is derived from processing trimmings. The company also report an average economic FCR (eFCR) of 1.45 for harvest-sized fish, which is aligned with data identified in scientific literature (Tlusty et al. 2011).

The Seafood Watch Feed Criterion considers the FFER from both fishmeal and fish oil and uses the higher of the two to determine the score. As demonstrated in Table 3, the fish oil inclusion level drives the FFER for farmed sablefish. As 59% of the fish oil used is from by-products, based on first principles, 1.07 tons of wild fish are required to provide sufficient fish oil to produce one ton of farmed sablefish, and results in a 5.1a – Feed Fish Efficiency Ratio (FFER) score of 7.32 out of 10.

Factor 5.1b – Sustainability of the Source of Wild Fish
The basic wild fish use score (Factor 5.1a) is adjusted based on the sustainability of the source fisheries for the production of fishmeal and fish oil. Factor 5.1b uses an average, or annual weighted mass-balance estimate of the fishery sources used in on-growing diets to decide the appropriate sustainability of the source of wild fish score. The Seafood Watch Standard allows a scoring adjustment to be made based on the sustainability of the source of wild fish with reference to wild fisheries Seafood Watch ratings, certifications by the Marine Stewardship Council (MSC)[37] or The Marine Ingredients Organisation (IFFO)[38], FishSource[39] scores, or other indicators of sustainability. According to data received from the operating company's feed supplier, all marine inputs used in their sablefish diets are either IFFO RS certified (i.e. Gulf menhaden and anchoveta) or sourced from processing trimmings (i.e. Alaska pollock, Chilean jack mackerel and North Pacific hake).

Table 4: Management quality and stock health status scores for wild capture species used in commercially manufactured diet used for the operating company's sablefish (FishSource database – https://www.fishsource.org)

FishSource Scores							
Common Name	**Scientific Name**	**Country Of Origin**	**Management Quality**			**Stock Health**	
		N-North C-Central S-South	**Management Strategy**	**Manager's Compliance**	**Fisher's Compliance**	**Current Health**	**Future Health**
Alaska Pollock	*Gadus chalcogrammus*	USA	10	10	10	7.3	8.4

[36] Also commonly referred to as the FFDR – Forage Fish Dependency Ratio or FIFO – Fish In: Fish Out Ratio
[37] https://www.msc.org
[38] http://www.iffo.net
[39] An online fisheries database which is maintained by the Sustainable Fisheries Partnership https://www.fishsource.org

Anchoveta	*Engraulis ringens*	S Peru/N Chile regions XV-I-II	≥ 6	≥ 8	≥ 8	≥ 6	≥ 6
Anchoveta	*Engraulis ringens*	C-S Chile regions V-X	≥ 6	10	≥ 6	≥ 6	7.4
Anchoveta	*Engraulis ringens*	C-S Chile regions III-IV	≥ 6	10	10	8	8.9
Chilean Jack Mackerel	*Trachurus murphyi*	Chile	≥ 6	10	≥ 8	7.5	9.2
Gulf Menhaden	*Brevoortia patronus*	USA	≥ 6	≥ 8	≥ 6	10	9.5
North Pacific Hake	*Merluccius productus*	USA	10	10	10	10	7.9

As shown in Table 4, all source fisheries utilized in the operating company's sablefish diets, including those where only trimmings are used, feature FishSource scores ≥ 6; thus the score for Factor 5.1b – Sustainability of the Source of Wild Fish is -4 out of -10. When combined, the Factor 5.1a and Factor 5.1b scores result in a final Factor 5.1 score of 6.47 out of 10.

Factor 5.2. Net Protein Gain or Loss

Table 5 provides a summary of the edible and non-edible protein inputs in the on-growing diet for sablefish, as per the data provided by the operating company's feed supplier. It should be noted that the protein content of fishmeal rendered from whole fish and from marine by-products is automatically calculated in the Seafood Watch scoring platform as 66.5%.

Table 5: The parameters used and their calculated values to determine the protein gain or loss in the production of farmed BC sablefish

Parameter	Feed data
Protein content of feed	46.0%
Percentage of total protein from non-edible sources (by-products, etc.)	58.26%
Percentage of protein from edible sources	35.81%
Percentage of protein from crop sources	18.75%
Feed conversion ratio	1.45
Protein INPUT per ton of farmed sablefish	253.9 kg
Protein content of whole harvested sablefish	18.0%
Percentage of farmed sablefish by-products utilized	100%
Utilized **protein OUTPUT** per ton of farmed sablefish	211.5 kg
Net protein gain or loss	-16.69%
Seafood Watch score (0-10)	8

These protein inputs are derived from fishmeal, terrestrial crop sources and land animal by-products. As shown, the average feed protein content is 46%; 17.06% of total feed protein comes from whole fish (edible) fishmeal, whereas 11.85% comes from (non-edible) by-product sourced fishmeal. For the remainder, 18.75% of total protein comes from terrestrial crop sources (considered to be 'edible'[40] protein inputs) and 46.41% comes from land animal by-products (considered not suitable for human consumption[41]). These data, when considered in conjunction with the company's stated eFCR of 1.45, show that the edible protein input is 25.39kg per 100kg of harvested sablefish (i.e. 253.9 kg per MT).

After an adjustment to incorporate the conversion of crop ingredients to farmed fish, the calculated protein output is 211.5 kg per MT of farmed sablefish production and a net edible protein loss of 16.69%. This results in a score of 8 out of 10 for Factor 5.2 – Net Protein Gain or Loss.

Factor 5.3. Feed Footprint

This factor is an approximate measure of the global resources used to produce aquaculture feeds (i.e. the inclusion levels of marine, terrestrial crop, and terrestrial land animal feed ingredients). These calculations are based on the average global ocean and land area used for production of one MT of farmed sablefish.

Table 6: The parameters used and their calculated values to determine the ocean and land area appropriated by feed ingredients in the production of farmed BC sablefish.

Parameter	Feed data
Marine ingredients inclusion	29%
Crop ingredients inclusion	26%
Land animal ingredients inclusion	41%
Ocean area (hectares) used per MT of farmed sablefish	10.94 ha
Land area (hectares) used per MT of farmed sablefish	0.79 ha
Total global area (hectares) used per MT of farmed sablefish	11.73 ha
Seafood Watch Score (0-10)	6

As shown in Table 6, the ocean area necessary for production of marine ingredients required to produce one MT of farmed sablefish is 10.94 ha. The land area necessary for production of terrestrial (crop and land animal) ingredients required to produce one MT of farmed sablefish is 0.79 ha. The combination of these two values results in an overall feed footprint of 11.73 ha/MT of farmed sablefish. This results in a final Factor 5.3 score of 6 out of 10.

Conclusions and final score

The final score for Criterion 5 – Feed is the average of the three factor scores with a double-weighting on Factor 5.1 – Wild Fish Use. The double-weighting is used because the direct harvest of wild fish is still considered to be the primary environmental concern of aquaculture feeds compared to the terrestrial production of feed ingredients from crops and land animals.

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[40] Note "edible" in this context relates to feed ingredients that would be suitable (or equivalent to those suitable) for human consumption.

[41] https://www.seafoodwatch.org/-/m/sfw/pdf/criteria/aquaculture/mbaseafood%20watchaquaculture%20standardversion%20a3.2.pdf?la=en

The score for Factor 5.1 - Wild Fish Use is 6.47; for Factor 5.2 - Net Protein Gain or Loss the score is 8, and for Factor 5.3 - Feed Footprint the score is 6: taken together, the scores for these three factors combine to give a final Criterion 5 – Feed numerical score of 6.73 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	6	
F6.1 Recapture adjustment	0	
F6.1 Final escape risk score		6
F6.2 Invasiveness		7
C6 Escape Final Score (0-10)		**6**
Critical?	NO	**YELLOW**

Brief Summary

By design, open net pen aquaculture systems are vulnerable to escape events. Robust management measures, in conjunction with the effective implementation of Best Management Practices (BMPs), can greatly diminish the potential for escapes to happen, and mitigate the severity of ensuing ecological consequences, should they occur. In order to remain licensed, all marine farms in BC must implement BMPs with regard to escapes by having an approved 'Escape Prevention and Response Plan' in place. Any escapes that do occur must be promptly reported by farm operators to DFO, which in turn make these data publicly available. To date, these public records do not include any incidents of farmed sablefish escaping. The operating company also attest that they have never knowingly had an escape event. While no escapes have ever been documented by the sector, and it is evident that BMPs are actively employed by the current industry, the Seafood Watch Standard nevertheless considers the potential risk of escapes occurring to be low-moderate since monitoring data in this regard cannot be robustly verified. However, according to the Standard, the ecological risk presented by such an eventuality is considered to be low. This is concluded because sablefish, which exhibit a high degree of genetic homogeneity throughout their range, are a native species in the waters of BC and, in addition to this, the broodstock used by the current industry are primarily wild-caught (80%), with the balance being the progeny of wild parents. When all of these factors are considered together, the final score for Criterion 6 – Escapes is 6 out of 10.

Justification of Rating
This Criterion combines two factors; Factor 6.1 assesses the risk of escapes based on the characteristics of the production system under review, whereas Factor 6.2 assesses the potential for competitive and genetic interactions and impacts should farmed fish escape into the wild. The potential for interbreeding between farmed fish and wild conspecifics is of concern due to the impact that this could have upon genetic diversity. In addition, escapees may also impact populations of wild fish by causing competition for prey and habitat.

Factor 6.1 Escape risk
Open production systems, such as the net pens employed by the operating company, are inherently vulnerable to escape events. Some factors that may contribute to such unforeseen events include: inclement weather, damage inflicted on nets by predators or saboteurs, equipment failure, poor handling and human error. However, escape risks can be mitigated by the implementation of effective Best Management Practices (BMPs) and such measures are a requirement for all marine farm license holders in BC and are also embedded in the DFO's Pacific Aquaculture Regulations. One of the conditions stipulated in the requisite 'Marine finfish aquaculture licence'[42], which is issued under the authority of the Fisheries Act, pertains to 'Escape Prevention, Reporting and Response'. The regulations that apply to this aspect of farm management, which require marine farms to deploy, manage and maintain cage structures and nets efficiently in order that escapes are prevented to the best of each operator's ability, can be summarized as follows:

- All containment structures must be designed, constructed, installed, maintained and repaired to preserve structural integrity and prevent the escape of cultured fish;
- Any containment structures or system components beyond repair are retired from service;
- All equipment must be designed to be compatible to ensure there is no chafing or weak points;
- Each stocked net pen must be assigned an inventory control number, which is clearly visible and permanently affixed to the structure;
- Jump nets must be installed at least one meter above the surface of the water at the top of any net pen that does not have a permanently attached mesh top or similar barrier;
- Containment nets and anti-predator nets must be kept taut at all times;
- The license holder must be able to demonstrate that net materials are strong enough to resist tearing;
- Nets must be tested, inspected and repaired by a qualified individual prior to being installed and when removed from the water;
- Above-water inspections of nets and containment systems must be conducted daily and any damage repaired immediately;

[42] http://www.pac.dfo-mpo.gc.ca/aquaculture/licence-permis/docs/licence-cond-permis-mar/index-eng.html

- Underwater inspections of containment systems by diver or a similar method must be conducted at least every 60 days and also prior to fish entry;
- In addition to the above, active nets must be inspected immediately after any operational activity or event that increases the risk of net failure, including but not limited to: harvesting, grading, extreme environmental conditions, net pen changes, fish delivery, recurring predator interactions, vandalism or towing of the active containment structure;
- Complete and detailed records must be maintained for the entire life of each net pen;
- The license holder must have in place an approved Escape Prevention and Response Plan (EPRP) including the means to prevent further escapes, recapture escaped fish, and rectify the deficiency that caused the escape.

The Escape Prevention and Response Plan (EPRP) provided by the operating company describes their policies, procedures, and infrastructure management with regard to the identification of potential situations where an escape could result, as well as swift response strategies to mitigate ecological impacts should such an event occur. In addition to the management strategies detailed in their EPRP, the operating company also implement a number of other routine practices that contribute to effective escape prevention at their net pen facilities. Every net has an integrated, reinforced predator exclusion net which consists of a heavy plastic net suspended 1 m below the inner net (pers. comm. Don Read, GESF, May 2018). One week prior to being stocked in net pens at 30g – 50g, fish are counted, weighed, and measured in the hatchery to ensure that the containment net they are to be stocked in is of the appropriate mesh size (pers. comm. Claire Li, GESF, December 2019). Given these measures, the risk of escapes is minimized, which is reflected in the operating company's current track record of zero reported escapes to date, as is further discussed below.

BC regulations stipulate that farm operators must report any escape incidents to DFO within 24 hours, including details of the location, species, number of escapees, plus their health status and size class. In turn, DFO publish these data - as and when they occur - on their 'Escapes of cultured marine finfish from BC aquaculture sites'[43] webpage. Operators must also submit a detailed written report within one week of the escape event; subsequently, collated details of all such reported incidents are published together in DFO's online 'Annual national escape reports'[44], which also include any reported data pertaining to recapture efforts. A review of these annual escape reports on DFO's website, which date back to 2010, do not indicate any reported incidences of farmed sablefish escaping net pen facilities. Likewise, the operating company also state that no reportable escape incidents have ever occurred at either of their sablefish farm sites during the time the company have been in operation, either under the present company structure (dating back to 2014) or earlier (back to 2007) (pers. comm. Claire Li & Terry Brooks, GESF, October 2019).

[43] https://open.canada.ca/data/en/dataset/691dd994-4911-433d-b3b6-00349ba9f24e
[44] http://www.dfo-mpo.gc.ca/aquaculture/protect-protege/escape-prevention-evasions-eng.html#annual

Despite the regulatory requirements that are in place, the DFO acknowledge that the number of escapes recorded in national reports are estimates, since it is challenging to determine the precise number of escapees involved when such events occur. In this regard, some researchers contest the numerical accuracy of reported escapes, particularly with reference to the BC Atlantic salmon sector, and also highlight the potential for trickle-losses, which may go unnoticed but accrue substantially over time (Fisher et al. 2014).

While the operating company have never experienced or reported an escape event at either of their farm sites, there is still an inherent risk of an escape event occurring due to the open nature of net pen cage structures. Despite this, the documented track record of no reported sablefish escapes, in combination with the escape prevention measures implemented demonstrates that the industry has effective management systems in place to mitigate the risk of escape (a score of 4 out of 10). Additionally, though there is risk associated with counting error and trickle losses, data regarding escape records are considered robust (a score of 8 out of 10). This justifies a significantly lower level of concern than typical open systems utilizing best management practices. As such, an intermediate initial score is given for Factor 6.1 – Escape Risk and is 6 out of 10.

Factor 6.2. Competitive and genetic interactions

Sablefish, which are widely distributed throughout the northern Pacific Ocean, are native to the waters of BC. Some literature notes the presence of two discrete populations; one northern and one southern. The northern waters of BC and Alaska are identified as the grounds of the northern biological stock, whereas the southern population is said to inhabit the southern waters off BC as well as Washington, Oregon and California. Literature that discusses the presence of these separate biological stocks also suggests that both populations are present together in the waters of southwest Vancouver Island and northwest Washington (NOAA 2018). However, a recent survey of this large geographic area, which used genetic tools to analyze sablefish stocks from the Bering Sea, Gulf of Alaska and off the US West Coast, did not detect any differences in the allele frequencies of sablefish sampled from these different regions. This study indicates that sablefish throughout these regions actually belong to a single gene pool (Fenske et al. 2019, Jasonowicz et al. 2017, Jasonowicz 2015); this hypothesis is lent further credence by the fact that tagging studies demonstrate that sablefish frequently traverse long distances throughout their range (ARFM 2017).

In assessing the potential genetic risk that farmed escapees pose to wild fish, the Seafood Watch Standard considers whether the cultured species in question is native or not and, if it is, how genetically similar it is to wild conspecifics. In consideration of BC farmed sablefish, this species is clearly native to the region in which it is farmed. Communications with the current industry also reveal that 80% of broodstock are wild caught, with the remaining 20% being comprised of F1s, i.e., domesticated for one generation only (pers. comm. Claire Li, GESF, July 2019). When these factors are taken into account, together with the apparent genetic homogeneity of wild stocks, the competitive and genetic risks that farmed sablefish escapees present to wild stocks are considered to be low, albeit with an incremental increase in risk presented by the F1 progeny. As the majority of farm stock is one generation domesticated (a score of 8 out of 10), with 20% being second generation (a score of 6 out of 10), the score assessed for Factor 6.2 is an intermediate 7 out of 10.

Conclusions and Final Score

Although no escapes have ever been documented by the sablefish sector, and it is evident that BMPs are actively employed, the Seafood Watch Standard considers the potential risk of escapes to be low-moderate since monitoring data in this regard cannot be robustly verified. However, the ecological risk presented by farmed sablefish escapees is considered to be low, since they are a native species in the region in which they are farmed, and the broodstock used by the current industry are primarily wild-caught (80%), with the balance being the progeny of wild parents. When the scores for Factors 6.1 and 6.2 are combined, this results in a final score of 6 out of 10 for Criterion 6 – Escapes.

Criterion 7: Disease; pathogen and parasite interactions

Impact, unit of sustainability and principle

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

Criterion 7 Summary

Disease Risk-based assessment		
Pathogen and parasite parameters	**Score**	
C7 Disease Score (0-10)	6	
Critical?	NO	**YELLOW**

Brief Summary

Literatures notes that sablefish is typically a hardy species; mortality data obtained from the sablefish sector indicates that less than 1% of farmed stocks succumb to disease, in respect of fish > 500g. The main disease that affects farmed sablefish is furunculosis, the causative agent of which is the bacterium *Aeromonas salmonicida*. Susceptibility to *Vibrio anguillarum* has also been demonstrated in disease exposure challenge studies with this species. The operating company have been using a furunculosis vaccine developed for Atlantic salmon with some success, and they are also collaborating with a Canadian lab to develop a bespoke sablefish vaccine for furunculosis, using bacterial isolates from the water body in which their farm is located. Research into the development of vaccines to protect sablefish against furunculosis is also taking place in the US. The conditions of license for marine farm operators in BC clearly stipulate a range of biosecurity measures and reporting requirements that must be followed by farms, including development of, and adherence to, a DFO approved fish Health Management Plan (HMP) plus the provision of regular reports detailing the health of fish stocks. Farm facilities may also be inspected to ensure their compliance in this regard. While no studies were identified that assessed the flow of pathogens between farmed sablefish and wild conspecifics - and despite the inherent design of open net pens that make this bidirectional flow of pathogens highly probable - it is unlikely that the current small-scale of the sablefish industry is a cause for concern in terms of the on-farm amplification and retransmission of disease to wild fish, particularly given that the present status of wild stocks is reportedly healthy. It is thus considered that the fish health management measures implemented by the current industry result in low, temporary or infrequent occurrences of infections or mortalities at the 'typical' farm level and the final score for Criterion 7 – Disease is 6 out of 10, which reflects a low-moderate concern for this aspect of production.

Justification of Rating

By design, open net-pen culture systems are inherently vulnerable to the transmission of pathogens between cages and also between wild and farmed fish stocks. It is, however, challenging to quantify such pathogenic exchanges and scant empirical evidence of these has ever been documented (Krkošek 2017). Since sablefish farming is not a well-developed sector, few data are available pertaining to the pathogenic susceptibilities of this species. As disease data quality and availability is moderate (i.e. a Criterion 1 – Data score of 5 for the disease category), the Seafood Watch Risk-Based Assessment was utilized.

One of the main mobilizers of aquatic pathogens are water currents, although other potential on-farm vectors include infected juveniles, equipment and feed. In 2005, an assessment of sablefish aquaculture, prepared by the University of British Columbia's Fisheries Centre, suggested a number of pathogens that could potentially impact the sector; these included *Anisakis* sp., *Flavobacterium branchiophila*, epitheliocystis, papillomatosis, *Pseudomonas* sp., *Dactlogyrus* sp., *Diplostomum* sp., *Trichoina* sp., *Vibrio (Listonella) anguillarum*, *Renibacterim salmoninarum* and *Aeromonas salmonicida* (Sumaila et al. 2005). Within the same timeframe, a study was undertaken at DFO's Pacific Biological Station to test the susceptibility of cultured sablefish to infectious hematopoietic necrosis virus (IHNV) and viral hemorrhagic septicemia virus (VHS), both of which are diseases that impact salmonids. However, this viral challenge study concluded that farmed sablefish were not susceptible to either of these diseases, and this was also found to be the case with wild sablefish (Clarke 2004). Disease challenges, using three varieties of vibrio, have also been conducted on farmed sablefish at NOAA's Newport Research Station in Oregon. Vibrios, which belong to the diverse Vibrionaceae family, are one of the most commonly occurring species of bacteria found in marine, estuarine and freshwater environments. These trials demonstrated that sablefish are significantly susceptible to *V. anguillarum,* exhibiting mortality rates up to 24%, dependent upon the level of exposure and the size of the fish, whereas they have a natural resistance to both *V. splendidus* and *V. ordalii* (Arkoosh & Dietrich 2015).

Literature notes that juvenile sablefish are typically a hardy species with low mortality rates observed (Luckenbach et al. 2017). This trait is also evident from production data provided by the operating company, which shows an average overall annual mortality of 1.16% in fish > 500 g produced between 2015 and 2018 (pers. comm. Claire Li, GESF, November 2019). As noted in Criterion 4 - Chemical Use, furunculosis is reportedly the only pathogen that presently impacts BC sablefish production. The causative agent of furunculosis, which causes lethal septicaemia, is the bacterium *Aeromonas salmonicida,* of which there are typical and atypical strains. In recent years, progress has been made in the efficacy of vaccines developed to combat this disease, and the operating company reports a declining trend in antibiotic use, particularly with new cohorts stocked in 2018 and 2019, due to the success of their vaccination strategy. Currently, this company utilizes a furunculosis vaccine developed for the Atlantic salmon sector but is also working with a lab to develop a sablefish-specific vaccine (pers. comm. Claire Li, GESF, September 2019). The Canadian laboratory that the company is collaborating with are developing a bespoke sablefish vaccine based on bacterial isolates collected in Kyuquot Sound, which should yield more targeted results with this company's stocks (pers. comm. Claire Li, GESF, September 2019).

Sablefish reportedly do not suffer from external parasites (pers. comm. Claire Li, GESF, May 2019, AAA 2010). The DFO website also notes that sea lice monitoring is not a requirement for sablefish facilities since this species is neither susceptible to, nor a carrier of, this parasite (DFO 2019d). The operating company monitor their fish stocks for internal parasites, although none have ever been detected (pers. comm. Claire Li, GESF, May 2019).

Regulatory requirements pertaining to biosecurity on marine farms in BC

As a condition of license, marine farm operators in BC must follow a DFO approved fish Health Management Plan (HMP), which describes the facility's management protocols for ensuring fish health and welfare, inclusive of water quality monitoring and biosecurity measures. Farms must report the results of their monitoring activities to DFO. Of note, while the HMP's and production facilities of salmon producers in BC are subject to regular inspections under the Fish Health Audit and Surveillance (FHAS) component of the Fish Health Program, sablefish producers are not part of the FHAS scheme. Sablefish producers may be still be targeted for a fish health audit by DFO fish health staff, although the current operator has evidently not been audited in this regard in recent years (pers. comm. Bernie John Taekema, DFO, October 2019).

To inform this Criterion, the operating company provided a copy of their facility's HMP, which succinctly describes the biosecurity and health management procedures that are in place to ensure the good health of fish stocks and the prevention of disease. This document is extensive in nature; for reference, some excerpts of the major topics addressed are included below:

- *Maintaining a clean, safe work environment will reduce the possibility for spread and exposure of fish to infectious or parasitic disease. Pathogens may be spread by sick fish and wild fish through the water, on shared equipment, or by inadvertent contact by personnel, visitors or their gear. Entrance of potential pathogens will be prevented or minimized by an effective biosecurity "barrier" at each facility. Biosecurity applies to all personnel (staff, divers, management), to all visitors and all equipment. Biosecurity includes three components:*
    - *Keeping fish healthy*
    - *Keeping pathogens out*
    - *Keeping disease from spreading within the site*
- *Keeping fish as healthy as possible is critical to preventing disease from coming on site and/or spreading within a site.*
- *Fish will be routinely monitored for signs of health and disease. All staff are familiarized with normal fish behaviour.*
- *Fish will be monitored at least once daily for any unusual behaviour, visible lesions or other signs of disease. Changes in behaviour and physical condition will be reported to site management.*
- *All efforts are made to minimize disease on site. Adequate hygiene, disinfection, and mortality collection help to keep fish healthy and exposed to as few pathogens as possible.*

- *Mortalities will be collected on a routine and frequent basis to minimize the potential spread of disease and to minimize attractiveness to predators.*
- *Management is responsible for ensuring a suitable rearing environment for the fish, so they can stay healthy. Facility requirements including nets are detailed in regulation; materials used in the construction and maintenance of holding areas are chosen to minimize potential harm to the fish. Staff are onsite 24/7.*

In addition to the biosecurity and health management measures included in their HMP, the operating company also typically employ very low stocking densities, never exceeding 10 kg/m^3.

As with any animal farming activity, some mortalities inevitably occur, and these must be monitored and accounted for. In this regard, marine farms in BC are required to submit quarterly 'Mortality by Category' reports to the DFO detailing numbers of fish mortalities and the reasons for these. These reports must include any therapeutants, pest control products or anaesthetics administered during the quarter. License conditions also stipulate that if an acute 'Mortality Event'[45] should occur, then an 'Urgent Notification', describing the circumstances of the event, must be submitted to DFO within 24 hours. This must subsequently be followed up with a detailed report within 10 days, the latter of which must define the number of dead fish, their total weight, or the percentage of the stock the mortality represents, as well as the cause of death. If mortality continues, then updated reports must be filed every 10 days until cessation of the mortality incident. As can be gleaned from DFO's 'Mortality events at British Columbia marine finfish aquaculture sites' online dataset[46], the sablefish sector have never reported a mortality event to date, and the absence of such occurrences is further affirmed by the operating company (pers. comm. Claire Li, GESF, October 2019).

In addition to reporting therapeutant use in their quarterly 'Mortality by Category' reports, marine farms in BC are also required to report 'Fish Health Events' to DFO. As described on the government website,[47] "*A fish health event is any suspected or active disease that occurs within an aquaculture facility that requires the involvement of a veterinarian and warrants mitigation measures (e.g., treatment, quarantine, reduction in density). As a condition of licence, company veterinarians must notify DFO within seven days of any fish health event on a farm*". A review of the 'Fish health events at British Columbia marine finfish aquaculture sites 2016 and ongoing' dataset on the government website[48] does not list any fish health events reported on behalf of the operating company – even though antibiotic use has been reported by the operating company on a number of occasions, as per entries included in the government's National Aquaculture Public Reporting (NAPR) datasets for 2016 and 2017[49]. This omission has been

[45] A mortality event is defined as: "(a) *Fish mortalities equivalent to 4000 kg or more, or losses reaching 2% of the current facility inventory, within a 24 hour period; or (b) fish mortalities equivalent to 10,000 kg or more, or losses reaching 5%, within a five day period*".
[46] https://open.canada.ca/data/en/dataset/7fbb2662-391a-4df7-99b4-3343fa68fc93
[47] https://open.canada.ca/data/en/dataset/deefd1d7-7184-44c7-83aa-ec0db91aad27
[48] https://open.canada.ca/data/en/dataset/deefd1d7-7184-44c7-83aa-ec0db91aad27
[49] https://open.canada.ca/data/en/dataset/288b6dc4-16dc-43cc-80a4-2a45b1f93383

referred to the relevant parties in order that entries in the fish health events database can be updated to concur with those included in the NAPR dataset.

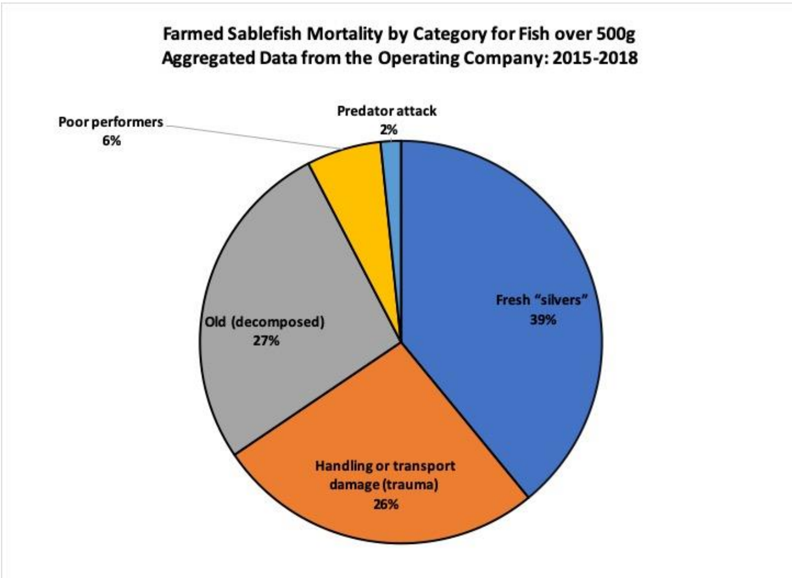

Figure 6: Aggregated 2015 - 2018 annual farmed sablefish 'Mortality by Category' breakdown, as reported to DFO by operating company (includes production > 500g only)

The operating company budget for a 10% annual loss of stocks from mortality, in consideration of fish above 5g (pers. comm. Claire Li, GESF, May 2019), and this would appear to be in line with the 'Mortality by Category' reports that they have filed with DFO in recent years. Figure 6 shows the operating company's aggregated annual 'Mortality by Category' breakdown for sablefish over 500g from 2015 to 2018. Mortalities accounted for 1.16% of the total inventory of fish > 500g produced over this period. If a 'worst-case scenario' is assumed, and 100% of 'Fresh silvers' and 100% of 'Old - decomposed' mortalities were due to disease, then this would equate to 66% of all mortalities being attributable to disease. Given that total mortalities accounted for 1.16% of the fish stocks > 500g raised over this time, the worst-case scenario is that just 0.77% of these stocks died due to disease.

While there is a broad body of literature regarding disease transfer risk between farmed salmonids and wild fish in British Columbia, there is limited information concerning the transfer of pathogens between farmed sablefish and wild fish (inclusive of salmonids); despite this, information from these studies can be applied in the context of farmed sablefish.

As stated, the primary pathogen of concern in farmed sablefish is *Aeromonas salmonicida*, the causative bacterial agent of furunculosis. A recent review of infectious agent occurrence in wild British Columbia salmonids (Jia et al. 2019), that assessed literature and DFO data dating back to 1970, indicates that the prevalence of *A. salmonicida* amongst wild salmonids is, overall, "*low and rarely reported*" and "*the proportion of cases of* [*A. salmonicida* have] *decreased in comparison with other pathogens*" in samples obtained by the DFO Fish Pathology Program since 1995. The review also notes that *A. salmonicida* is more commonly detected in hatchery salmonids as compared to wild, and vaccines developed by the aquaculture sector in recent years may reduce the exposure risk of wild fish around farms. Further, although data concerning the transfer of pathogens between farmed and wild sablefish is lacking, it is relevant to note that the Canadian sablefish fishery, which is managed jointly between the DFO and the

Canadian Sablefish Association (CSA)[50], is reportedly in good health at the present time and appears to be on an upward trend in terms of biomass (Fenske et al. 2019).

Given the low mortality rates attributable to disease on sablefish farms, the recent vaccine efficacy developments, and low prevalence of *A. salmonicida* in wild fish, it is unlikely that pathogen numbers on wild fish are amplified due to farm-to-wild transmission.

Conclusions and Final Score

Although there are clearly a number of pathogens that impact sablefish, particularly furunculosis, no studies were identified that assessed the flow of pathogens between farmed sablefish and wild conspecifics. Literature that reviewed infectious agent occurrence in wild salmonids in BC found the prevalence of *A. salmonicida*, the primary pathogen affecting farmed sablefish, to be low and rarely reported. It is evident that some disease-related mortalities do occur in the sablefish sector and that open net pens are inherently vulnerable to introductions of local pathogens and parasites, as they are to discharging pathogens into the surrounding environment. In consideration of the low production volume of the current industry and the low stocking densities employed, this farming activity would not appear to present a high concern in terms of amplification and retransmission of disease to wild fish, particularly with the degree of biosecurity measures stipulated under the license conditions for marine farms in BC. When all of these factors are taken into consideration, alongside industry mortality data that indicates disease-related mortalities account for less than 1% of farmed sablefish stocks > 500 g, it is considered that fish health management measures result in low, temporary or infrequent occurrences of infections or mortalities at the ‘typical’ farm level, thus the final numerical score for Criterion 7 – Disease is 6 out of 10, which reflects a low-moderate concern for this aspect of production.

[50] https://www.canadiansablefish.com

Criterion 8X: Source of Stock – independence from wild fisheries

Impact, unit of sustainability and principle

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

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

Criterion 8X Summary

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

Brief Summary

The present solo commercial producer of farmed sablefish supply their two on-growing cage sites with juveniles produced in their own hatchery. The company also have an on-site broodstock program, however this facility is still reliant to a large extent on wild-caught broodstock. Approximately 80% of the broodstock used to produce juveniles come from wild fisheries, since the technology needed to use 100% domesticated broodstock is still in development. The wild broodstock that the company catch come from local fisheries that are considered to be a 'Good Alternative – Yellow' choice by the Seafood Watch program, with a 'Green' stock status ranking. As such there is no deduction for this Criterion and the score for Criterion 8X – Source of Stock is of 0 out of -10.

Justification of Rating

This Criterion assesses the sustainability of the source of farmed stock, taking into account both the source of juveniles used in production as well as broodstock. As discussed elsewhere in this report, the sablefish aquaculture sector is still in a formative stage of development, thus efforts toward the refinement of larval rearing protocols for sablefish are ongoing, as is evident in literature pertaining to sablefish hatchery research and development initiatives (Cook et al. 2017, Luckenbach et al. 2017). One hundred percent of the juveniles stocked by the operating company are hatchery-raised, and these originate from the company's own hatchery, located off the southeast coast of Vancouver Island (Leeuwis 2017, HI 2016, ANA 2013). As with sablefish larval rearing technology, current research into F1 broodstock manipulation is also in a formative stage of development. The operating company's hatchery facility incorporates its own broodstock program, which was initially established in 2003 (HI 2016). Around 400 broodstock are maintained on-site and these are comprised of approximately 80% wild-sourced and 20% F1 generation sablefish (pers. comm. Claire Li, GESF, July 2019). When wild broodstock are collected, this is done locally and under permit and can be up to 75 fish per year (pers. comm. Don Read, May 2018). At present, 0.1% of Canada's total allowable catch (TAC) for sablefish is allocated to the aquaculture sector for the purpose of facilitating broodstock collection[51]. If the source of wild-caught broodstock can be demonstrated to be of minimal concern, the Seafood Watch Standard does not consider their use to be a negative driver for this Criterion. Since all Seafood Watch recommendations for wild-caught Canadian sablefish are rated Yellow (i.e. a 'Good Alternative') and they are not considered to be overfished (earning a Green stock status criterion rating)[52], this wild broodstock collection does not incur any deduction in the scoring of this Criterion at the current levels employed by the sector. In addition to ongoing developments in Canada, with regard to the development of a domesticated broodstock program, progress in this regard is also underway at NOAA's Northwest Fisheries Science Center Manchester Research Station[53].

Also of note, Fenske et al. (2019) state in a NOAA report that "*The status of the B.C. sablefish stock is judged on the scale of the OM* [operating model] *which was last updated in 2016. Based on this 2016 assessment sablefish lie in the Cautious Zone between the target and limit reference points under the DFO FPA Framework* [i.e. Harvest Decision-Making Framework Incorporating the Precautionary Approach]. *However, as a result of recent above-average recruitment attributed to the 2014 year class, the biomass of sablefish in B.C. appears to be increasing. Based on the most recent estimates of sablefish catch and survey CPUE* [Catch-per-unit-effort] *from the 2017 research and assessment survey, the current point estimate of legal-size sablefish biomass in B.C. is 31,264 t*".

Conclusions and Final Score

One hundred percent of BC's farmed sablefish are produced from hatchery raised juveniles, thus all harvested fish are of domestic origin. Although around 80% of the operating company's farmed stock is dependent on wild-sourced broodstock (i.e. wild fisheries), these local Canadian wild sablefish stocks are considered to be healthy and overfishing is a low concern. The final numerical score for Criterion 8X – Source of Stock is a deduction of 0 out of -10.

[51] https://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/ground-fond-ifmp-pgip-sm-eng.html
[52] https://www.seafoodwatch.org/-/m/sfw/pdf/reports/g/mbaseafoodwatchgroundfishbritish%20columbiareport.pdf
[53] https://www.nwfsc.noaa.gov/research/divisions/efs/marinefish/finfish/sablefishbroodstocks.cfm

Criterion 9X: Wildlife and predator mortalities

Impact, unit of sustainability and principle

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

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

Criterion 9X Summary

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0-10)	-1	
Critical?	NO	GREEN

Brief Summary

At the industry-wide level, data show that wildlife and predator mortalities caused by interactions with marine farm installations in BC are limited to exceptional cases. Notably, impacts on marine mammals have declined dramatically across the sector in recent years. Although the operating company do experience predator and wildlife interactions at both of their farm sites, the low stocking densities used likely pose less of an attractant than those employed by more intensive production systems and effective management and prevention measures would appear to be in place. The company have not reported any wildlife or predator mortalities over the last 5 years, asides from the occasional mortality of incidentally caught wild fish. All incidental capture of wild fish in marine net pens in BC must be documented and reported upon to DFO and farmers must also release these incidentally caught wild fish in accordance with regulations. Although the majority of wild fish that are incidentally captured in this way are released unharmed, the details of any mortalities that do occur in this regard are made publicly available on DFO's website. A review of these online data indicate that the operating company have reported a number of incidents of wild fish being killed accidentally in this fashion; all of these species are from healthy stocks, asides from the copper rockfish, which is placed in the 'Avoid' category in Seafood Watch's wild capture recommendations. The number of copper rockfish impacted in this way is low, however, and is not considered to have a significant, detrimental effect on wild fish populations. The Seafood Watch Standard makes no scoring deduction when there is "*No direct or accidental mortality of predators or wildlife,*" however, to account for the limited impact on copper rockfish, a deduction of 1 has been made and the final score for Criterion 9X – Wildlife and Predator Mortalities is -1 out of -10.

Justification of Rating

This criterion is a measure of the effects of deliberate or accidental mortality on the populations of predators or other wildlife by the production system under consideration.

License conditions for marine farm facilities in BC stipulate that farm operators must take all reasonable measures to minimize wildlife and predator interactions, including the avoidance of incidental wild fish capture inside net pens. In order to achieve this, farms must develop a predator management plan which will be determined by the specific characteristics of their site. Such measures include the prompt removal of mortalities, in order that predators are not attracted in the first instance, as well as barriers, such as the installation of top nets to deter birds, and double walled net-pens and anti-predator nets to deter marine mammals, such as seals and sea lions, plus fencing to keep out sea otters. Predator management plans are audited during DFO site inspections to ensure that effective measures are in place.

The operating company report that they have never had any on-farm mortalities during the last five years (pers. comm. Claire Li, GESF, May 2019) and have never used lethal force against any predators, to date (pers. comm. Don Read, May 2018). The company use custom-made, reinforced sablefish predator nets in all of their cages; these are designed to provide 100% protection from marine mammals and consist of a heavy black plastic net suspended one meter below the inner net. Bird nets are also installed on the top of net pens (pers. comm. Don Read, May 2018). In accordance with DFO requirements, the operating company have a predator management plan in place, which includes a 'Non-Lethal Deterrent for Marine Mammals SOP' and a 'Predator Avoidance Plan', the latter of which states:

- *Predator exclusion nets will be installed at the discretion of the Site Supervisor*
- *In the absence of predator exclusion nets, net cages are constructed with a secondary bottom (shark guard) or semi-rigid bottom that deters dogfish from accessing mortalities within the net*
- *Nets extend at least one meter above the water level to deter access by predators*
- *Appropriate mesh size nets are used to grow fish while minimizing the number of wild fish which can enter the net*
- *Where applicable, electrical fences will be installed and maintained in working condition*

Additionally, the operating company have a 'Lethal Dispatch of Marine Mammals SOP' which lists potential marine mammal predators in the vicinity as: "California sea lions, seals, otters, humpback whales and grey whales" (pers. comm. Claire Li, GESF, May 2019).

A review of the company's 'Mortality by Category' reports that have been filed with DFO during recent years indicate that approximately 2% of mortalities have been attributable to predator attacks (as shown in Figure 6), with respect to fish > 500g. In 2015, one particularly impactful and unusual event that lead to a spike in predator related mortalities of the company's fish stocks occurred when a family of river otters entered the pen. The river otters subsequently exited the pen without intervention and since this time, if predator activity (almost always river otters) is noted around the farm, electric fences are activated. These are installed around the pens at approximately 30 cm above the water line. This prevents the otters from being able to climb up the netting into the pen. The operating company also report that they have never experienced an incident of a predator tearing open a pen, although sea lions do very rarely approach (pers. comm. Claire Li, GESF, July 2019). It should also be taken into account that the operating company employ very low stocking densities, typically never exceeding 10 kg/m^3, which likely minimizes the attraction of predators to the cage array.

The Marine Mammal Regulations (MMR), which are housed under the Fisheries Act, govern predator control issues across the whole of Canada. Previously, under the Pacific Aquaculture Regulations (PAR), licensed marine farm operators in BC were permitted to kill California sea lions or harbour seals if they were considered to be a threat to human lives or the farm, but such lethal control measures were only permitted if all reasonable actions to otherwise deter these predators had been taken and failed. However, these license conditions were amended on February 28th 2020, and all lethal dispatch measures are now impermissible, regardless of the circumstances; this licensing update applies to all finfish farms in BC. Since these marine mammal kill provisions have now been revoked, accidental drowning deaths should be the only potential cause of marine mammal fatalities in future (pers. comm. Kerra Shaw, DFO February 2020). Any such incidents must be reported to DFO, which in turn reports these occurrences publicly on their website[54]. As noted, the operating company have never recorded a marine mammal mortality in this database.

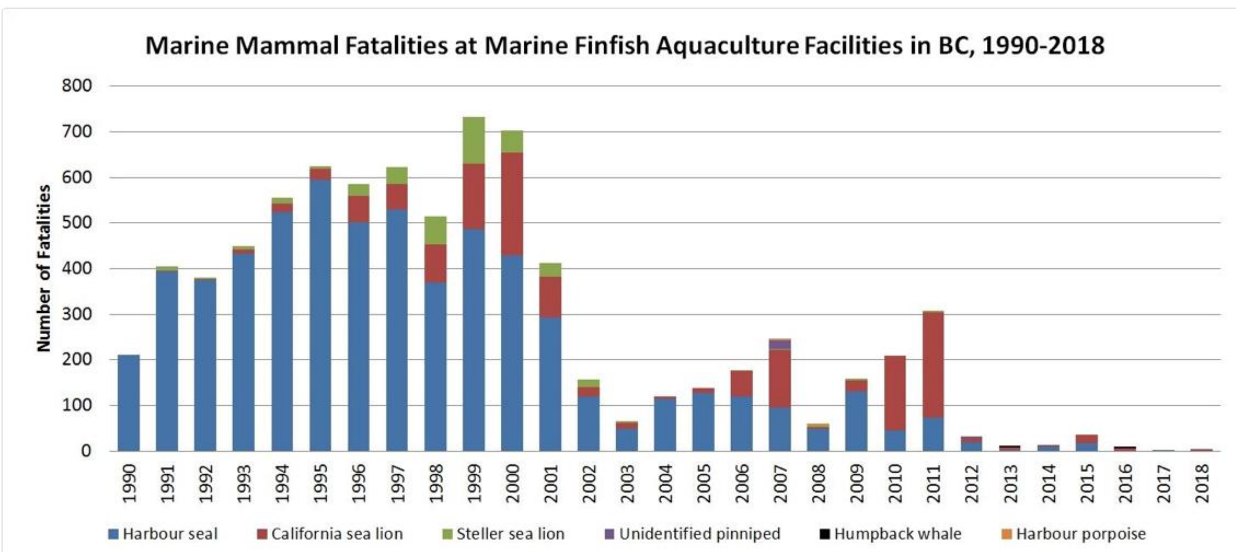

Figure 7: Marine mammal fatalities at marine finfish aquaculture facilities in BC, 1990 – 2018 (DFO. 2019f)

As is evident in Figure 7, which provides an overview of marine mammal fatalities at BC fish farms between 1990 and 2018, such mortalities have declined dramatically in recent years. Humpback whales, which do not use echolocation, are reportedly the species of whale most

[54] http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/mar-mam/index-eng.html

likely to become entangled in a marine farm installation or in fishing gear in BC. Cetacean entanglements must be reported immediately by farmers to DFO in order to allow the best chance of release and details of all successful releases are also made publicly available on DFO's website[55]

Another aspect of predator and wildlife interactions that marine farm operators must record and report upon is the incidental capture of wild fish[56] (FFE 2015); this situation can arise if wild juvenile fish enter the net pen when they are small and are subsequently retained in the cage as they grow. Farms are required to keep a logbook documenting such incidental catches and must release these back into the wild in the least harmful manner possible when the cage is transferred or harvested. The majority of incidentally caught fish are reportedly released in this manner, unharmed (pers. comm. Kerra Shaw, DFO January 2020). If a farm reports any such incidental captures that have resulted in a wild fish mortality event, these details are collated together with BC-wide data and made publicly available on DFO's website on their 'Incidental catch at BC marine finfish aquaculture sites' webpage[57]. A review of these online data indicate that the operating company have, on a number of occasions, reported a wild fish mortality event occurring as a result of incidental capture. The following species were reported as being impacted in this regard between 2015 and 2018: codfish, copper rockfish, Pacific herring, Pacific Ocean perch, pilchard, shiner perch, and surfperch. The number of each type of fish that were captured and accidentally killed during this three year period is shown in Table 7.

Table 7: Type and quantity of fish accidentally caught and killed in sablefish cages belonging to the current operating company from 2015 - 2018 (data extracted from DFO's 'Incidental catch at BC marine finfish aquaculture sites' webpage[58])

Common name	Scientific name	Number of Incidental Catches
Codfish	Family Gadidae	60
Copper Rockfish	*Sebastes caurinus*	24
Pacific Herring	*Clupea pallasii*	477
Pacific Ocean Perch	*Sebastes alutus*	177
Pilchard	*Sardinops sagax*	2
Shiner Perch	*Cymatogaster aggregata*	541
Surfperch	Family Embiotocidae	107

With reference to Table 7, shiner perch is listed as a species of 'Least Concern' on the IUCN Red List[59], as are pilchards (*Sardinops sagax*) caught in BC[60]. Surfperch is the group name for the Embiotocidae family (which includes shiner perch), and while those members of this family

[55] https://open.canada.ca/data/en/dataset/a7b3fdfb-5917-4ca6-b29c-093e3f65d6ba
[56] http://www.dfo-mpo.gc.ca/aquaculture/protect-protege/removal-fish-retraits-poissons-eng.html
[57] https://open.canada.ca/data/en/dataset/0bf04c4e-d2b0-4188-9053-08dc4a7a2b03
[58] https://open.canada.ca/data/en/dataset/0bf04c4e-d2b0-4188-9053-08dc4a7a2b03
[59] https://www.iucnredlist.org/species/192929/131006966
[60] https://www.iucnredlist.org/species/183347/143831586

listed on the IUCN Red List website are all categorized as being of 'Least Concern'[61], it is not possible to determine the specific species affected by incidental capture from this DFO dataset. This is also the case with codfish, since this group term refers to the family Gadidae and the specific species affected are not identified. However, Seafood Watch recommendations for two regionally prominent members of this family, Pacific cod and lingcod caught in BC, includes both species in the 'Good Alternative' category[62] (and BC lingcod caught using set longlines is a 'Best Choice'). Likewise, Pacific herring (*Clupea pallasii*) caught in BC is rated as a 'Good Alternative' by Seafood Watch[63], as is Pacific Ocean perch (*Sebastes alutus*)[64]. Copper Rockfish, however, is placed in the 'Avoid' category in Seafood Watch's wild capture recommendations[65]. Despite this ranking for copper rockfish, the low volume of catch (24 copper rockfish over a three year period), indicates that the activities of the farm do not have a significant detrimental impact on wild fish populations in this regard.

Conclusions and Final Score

Industry-wide aquaculture data show that mortalities of predators and wildlife caused by their interactions with marine farms in BC has been limited to exceptional cases in recent years. Any mortalities that have occurred are not considered to have a significant impact on the population sizes of these species and effective management and prevention measures would appear to be in place, including the employment of low stocking densities. While the operating company's farm sites do attract and interact with predators and other wildlife, zero mortalities of these have been reported by farm staff during the last 5 years – asides from a number of incidentally caught wild fish species. All of these incidentally caught wild fish species are from healthy stocks except the copper rockfish, which is ranked as a fish to 'Avoid' in Seafood Watch's wild capture recommendations. The Seafood Watch Standard makes no scoring deduction when there is "*No direct or accidental mortality of predators or wildlife,*" however, to account for the limited impact on copper rockfish, a deduction of 1 has been made and the final numerical score for Criterion 9X – Wildlife Mortalities is -1 out of -10.

[61] https://www.iucnredlist.org/search?taxonomies=100444&searchType=species
[62] https://www.seafoodwatch.org/-/m/sfw/pdf/reports/g/mbaseafoodwatchgroundfishbritish%20columbiareport.pdf
[63] https://www.seafoodwatch.org/-/m/sfw/pdf/reports/h/mbaseafoodwatchpacificherringbritish%20columbiareport.pdf
[64] https://www.seafoodwatch.org/-/m/sfw/pdf/reports/g/mbaseafoodwatchgroundfishbritish%20columbiareport.pdf
[65] https://www.seafoodwatch.org/-/m/sfw/pdf/reports/g/mbaseafoodwatchgroundfishbritish%20columbiareport.pdf

Criterion 10X: Escape of secondary species

Impact, unit of sustainability and principle

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

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

Criterion 10X Summary

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

Brief Summary

Production of farmed sablefish in BC, Canada is not considered to present a risk with regards to the unintentional trans-waterbody shipment of non-native species, since movements of juveniles and broodstock are limited to the local area. Because no deduction is warranted, the assessed score for Criterion 10X – Escape of Secondary Species is 0 out of -10.

Justification of Rating

The Seafood Watch Standard notes that: "*Trans-waterbody movement is defined with the source waterbody being ecologically distinct from the destination (farming) waterbody, such that the animal movements represent a risk of introducing non-native species*."

Factor 10Xa International or trans-waterbody live animal shipments

As discussed in Criterion 8X: Source of Stock, the juveniles used to stock the operating company's farm sites are produced in the company's own sablefish hatchery. The hatchery has an on-site broodstock facility, which includes a contingent of F1 fish but is predominantly comprised of wild-caught sablefish obtained from local fisheries. All movements of juveniles and broodstock are thus conducted at a local scale. In BC, all intentional movements of fish and shellfish between aquaculture facilities are regulated by the Introductions and Transfers Committee (BC ITC)[66], an entity that is comprised of both federal and provincial government members from the DFO, the BC Ministry of Environment, the Lands & Natural Resource Operations, and the BC Ministry of Forests. Each transfer application is evaluated for the potential risks the proposed movement poses genetically, pathogenically and ecologically; if

[66] http://www.dfo-mpo.gc.ca/aquaculture/management-gestion/contact-intro-eng.htm

these risks cannot be mitigated, the transfer application will be declined[67]. The same rules that apply to salmon movements, in this regard, apply to sablefish transfers (pers. comm. Bernie John Taekema, DFO November 2019). This process implements a zoning mechanism that identifies different biosecurity zones based on watersheds throughout the region, as shown in the 'Salmonid transfer zones (BC)' map[68] on DFO's website. In reference to these designated zones, the operating company's hatchery and cage sites are all located in Southern Coast Zone 7. In consideration of the above, the operating company's fish transfer activities are not considered to present a risk of invasive alien species being unintentionally transported alongside the principle farmed species during animal shipments, thus the score for Factor 10Xa is 10 out of 10.

Factor 10Xb Biosecurity of source/destination

Since there are no international or trans-waterbody shipments of live animals, there is no risk of transferring organisms between ecologically distinct environments. The score for Factor 10Xb is 10 out of 10.

Conclusions and final score

Since production of farmed sablefish in BC, Canada does not require juveniles or broodstock to be trans-shipped out with the range of the contiguous waterbodies to which they are native, there is no deduction for this Criterion. The final numerical score for Criterion 10X – Escape of Secondary Species is 0 out of -10.

[67] https://open.canada.ca/data/en/dataset/700fe290-7653-49e1-b961-741dc1ead924

[68] http://www.dfo-mpo.gc.ca/aquaculture/bc-cb/maps-cartes-eng.html

Overall Recommendation

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

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

Criterion	Score	Rank	Critical?
C1 Data	7.50	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	6.27	YELLOW	NO
C4 Chemicals	8.00	GREEN	NO
C5 Feed	6.73	GREEN	NO
C6 Escapes	6.00	YELLOW	NO
C7 Disease	6.00	YELLOW	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-1.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**47.50**		
Final score (0-10)	**6.79**		

OVERALL RANKING

Final Score	6.79
Initial rank	GREEN
Red criteria	0
Interim rank	GREEN
Critical Criteria?	NO

FINAL RANK

GREEN

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

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Appendix 1 - Data points and all scoring calculations

Criterion 1: Data quality and availability			
	Data Category	**Data Quality (0-10)**	
	Industry or production statistics	10	
	Management	10	
	Effluent	7.5	
	Habitats	7.5	
	Chemical use	7.5	
	Feed	5	
	Escapes	5	
	Disease	5	
	Source of stock	7.5	
	Predators and wildlife	7.5	
	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)	**8**	**GREEN**
	Critical?	NO	
Criterion 3: Habitat			
Factor 3.1. Habitat conversion and function			
	F3.1 Score (0-10)	7	
Factor 3.2 – Management of farm-level and cumulative habitat impacts			
	3.2a Content of habitat management measure	3	
	3.2b Enforcement of habitat management measures	4	
	3.2 Habitat management effectiveness	**5**	

	C3 Habitat Final Score (0-10)	**6**	**YELLOW**
	Critical?	NO	
Criterion 4: Evidence or Risk of Chemical Use			
	Chemical Use parameters	**Score**	
	C4 Chemical Use Score (0-10)	**8**	
	C4 Chemical Use Final Score (0-10)	**8**	**GREEN**
	Critical?	NO	
Criterion 5: Feed			
5.1. Wild Fish Use			
	Feed parameters	**Score**	
	5.1a Fish In : Fish Out (FIFO)		
	Fishmeal inclusion level (%)	20	
	Fishmeal from by-products (%)	41	
	% FM	11.8	
	Fish oil inclusion level (%)	9	
	Fish oil from by-products (%)	59	
	% FO	3.69	
	Fishmeal yield (%)	22.5	
	Fish oil yield (%)	5	
	eFCR	1.45	
	FIFO fishmeal	0.76	
	FIFO fish oil	1.07	
	FIFO Score (0-10)	**7.32**	
	Critical?	NO	
	5.1b Sustainability of Source fisheries		
	Sustainability score	-4	
	Calculated sustainability adjustment	-0.86	
	Critical?	NO	
	F5.1 Wild Fish Use Score (0-10)	**6.47**	
	Critical?	NO	
5.2 Net protein Gain or Loss			
	Protein INPUTS		

	Protein content of feed (%)	46	
	eFCR	1.45	
	Feed protein from fishmeal (%)		
	Feed protein from EDIBLE sources (%)	38.06	
	Feed protein from NON-EDIBLE sources (%)	61.94	
	Protein OUTPUTS		
	Protein content of whole harvested fish (%)	18	
	Edible yield of harvested fish (%)	59	
	Use of non-edible by-products from harvested fish (%)	100	
	Total protein input kg/100kg fish	66.7	
	Edible protein IN kg/100kg fish	25.39	
	Utilized protein OUT kg/100kg fish	21.15	
	Net protein gain or loss (%)	-16.69	
	Critical?	NO	
	F5.2 Net protein Score (0-10)	**8**	
5.3. Feed Footprint			
	5.3a Ocean Area appropriated per ton of seafood		
	Inclusion level of aquatic feed ingredients (%)		29
	eFCR		1.45
	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)		10.94
	5.3b Land area appropriated per ton of seafood		
	Inclusion level of crop feed ingredients (%)		26
	Inclusion level of land animal products (%)		41
	Conversion ratio of crop ingredients to land animal products		*2.88*
	eFCR		1.45
	Average yield of major feed ingredient crops (t/ha)		*2.64*
	Land area appropriated (ha per ton of fish)		0.79
	Total area (Ocean + Land Area) (ha)		11.73
	F5.3 Feed Footprint Score (0-10)		6
Feed Final Score			
	C5 Feed Final Score (0-10)	**6.73**	**GREEN**

	Critical?	**NO**	
Criterion 6: Escapes			
	6.1a System escape Risk (0-10)	6	
	6.1a Adjustment for recaptures (0-10)	0	
	6.1a Escape Risk Score (0-10)	**6**	
	6.2. Invasiveness score (0-10)	**7**	
	C6 Escapes Final Score (0-10)	**6**	**YELLOW**
	Critical?	**NO**	
Criterion 7: Diseases			
	Disease Evidence-based assessment (0-10)		
	Disease Risk-based assessment (0-10)	6	
	C7 Disease Final Score (0-10)	**6**	**YELLOW**
	Critical?	NO	
Criterion 8X: Source of Stock			
	C8X Source of stock score (0-10)	0	
	C8 Source of stock Final Score (0-10)	**0**	**GREEN**
	Critical?	NO	
Criterion 9X: Wildlife and predator mortalities			
	C9X Wildlife and Predator Score (0-10)	**-1**	
	C9X Wildlife and Predator Final Score (0-10)	**-1**	**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)		10.00	
C10X Escape of secondary species Final Score (0-10)		**0.00**	**GREEN**
Critical?		n/a	