Chinook (King) Salmon

Oncorhynchus tshawytscha

New Zealand

Marine and freshwater net pens

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Disclaimer

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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 bio secure 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

Chinook (King) salmon farmed in marine net pens in New Zealand

Criterion	Score	Rank	Critical?
C1 Data	8.60	GREEN	
C2 Effluent	6.00	YELLOW	NO
C3 Habitat	7.00	GREEN	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	5.06	YELLOW	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	8.00	GREEN	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	-4.00	YELLOW	NO
C10X Secondary species escape	-3.6	YELLOW	NO
Total	**47.20**		
Final score (0-10)	**6.78**		

OVERALL RANKING

Final Score	**6.78**
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 score for Chinook salmon farmed in marine net pens in New Zealand is 6.78 out of 10, with no red-ranked criteria. The final ranking is Green with a recommendation of Best Choice.

Chinook (King) salmon farmed in freshwater net pens in New Zealand

Criterion	Score	Rank	Critical?
C1 Data	8.60	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	9.33	GREEN	NO
C4 Chemicals	10.00	GREEN	NO
C5 Feed	4.74	YELLOW	NO
C6 Escapes	10.00	GREEN	NO
C7 Disease	8.00	GREEN	NO
C8X Source	0.00	GREEN	NO
C9X Wildlife mortalities	0.00	GREEN	NO
C10X Secondary species escape	-3.6	YELLOW	NO
Total	**54.88**		
Final score (0-10)	**7.87**		

OVERALL RANKING

Final Score	7.87
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 score for Chinook salmon farmed in freshwater net pens in New Zealand is 7.87 out of 10, with no red-ranked criteria. The final ranking is Green with a recommendation of Best Choice.

Executive Summary

Chinook (king) salmon were first introduced to New Zealand (NZ) in the late 1800s from California for the purposes of starting a commercial fishery. Despite ongoing stocking by the government, there has never been a commercial wild Chinook fishery in NZ, but the species became fully established before marine farming started in the South Island during the 1980s. The aquaculture industry has continued to grow steadily, and total annual production of farmed Chinook in NZ is approximately 14,000 metric tons (14,339 MT in 2018).

All Chinook salmon cultivated in NZ are initially reared in tanks in freshwater hatcheries and then transferred to a grow-out site, either in the freshwater or marine environment. Over 80% of Chinook production is marine based with two dominant companies operating in the Marlborough Sounds (NZ King Salmon, hereafter NZKS) and Big Glory Bay/Stewart Island (Sanford) representing 60% and 22% of marine production, respectively. NZKS produces approximately 8,600 metric tons (MT) and Sanford produces 3,400 MT of salmon annually (Aquaculture NZ, 2019). Mount Cook Alpine Salmon (hereafter MCAS) in Canterbury produces the bulk of freshwater Chinook salmon, at approximately 1,700 MT annually. Roughly 70% of Chinook salmon from NZ is exported to nearly 50 countries, but half (51% or 2,516 MT in 2018) is imported by the US.

This Seafood Watch assessment involves criteria covering impacts associated with effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability. The assessment focuses on the three main producers (there are two additional small companies, one marine and one in freshwater), and analyzes marine farms (NZKS and Sanford) separately from freshwater (MCAS) to generate marine and freshwater scores based on the Seafood Watch criteria.

Criterion 1: Data Quality and Availability

A large amount of specific information and data on marine and freshwater Chinook farms is available in New Zealand. The main companies provided farm- and company-specific data, and further information is available from regional councils, feed companies, environmental regulators, and certification bodies, in addition to the general and NZ-specific academic literature on salmon farming. This assessment acknowledges the potential limitations of company-reported data, but overall the data gives high confidence that the industry and its impacts are understood. Overall, data availability and quality are high throughout the NZ Chinook salmon industry. There is some uncertainty around the ability of available data to accurately inform the assessment regarding the risk of impacts to habitat/effluent, disease/chemical use, unobserved mortalities, industry production statistics and introduction of secondary species. These aspects received data availability scores of 7.5 out of 10. The final score for Criterion 1 – Data quality and availability is 8.6 out of 10 for both marine and freshwater farms, with a final score of 8.4 out of 10 for Criterion 1—Data quality and availability.

Criterion 2: Effluent
Salmon farming companies in New Zealand have considerable variability in their consent requirements (e.g., nitrogen levels, total feed discharge, chlorophyll *a*, and DO and allowable benthic impacts) depending on the location of the farm (in high or low flow areas), the associated regional council, and also the age of the consent. Annual monitoring of water quality is administered under some consents and the reports are provided to the relevant regional council. NZKS reports are publicly available and MCAS and Sanford provided reports and third-party assessments for the purposes of this assessment.

Regarding impacts beyond the immediate farm area, though available data show no evidence that effluent discharges have substantial impacts beyond the Outer Limit of Effect (OLE) the OLE distances from the net pens are high (300 m and up to 600 m at some sites), and a significant impact (i.e., an Enrichment Scale (ES) of approximately 3 where 1 is pristine) is observed and permitted at 300 m (and up to 600 m at some high flow sites). This indicates some potential for cumulative waterbody impacts, and a precautionary score of 6 out of 10 for marine farms has been set for Criterion 2 – Effluent. Evaluation of the monitoring reports from freshwater farms show general compliance and that water quality parameters outside the allowable zone of effect are similar below and above the farms. Thus, there is little concern that effluent discharges cause or contribute to cumulative impacts at the waterbody/regional scale. As a result, the final score for Criterion 2 – Effluent for freshwater farms is 8 of 10.

Criterion 3: Habitat
Marine farms in NZ are located in coastal inshore sub-tidal areas. Annual monitoring of results from 1998 to 2016 show that high enrichment may occur within the immediate farm area, particularly in shallower and/or lower flow locations, but further research indicates that in most cases, these impacts are rapidly recoverable. Freshwater farms are located in hydroelectric canals previously constructed for energy generation purposes, and there are not considered to be any further impacts on habitats or their ecosystem services as a result of the farm's construction or operation.

National legislation in NZ guides decisions around sustainable development of the coastal and freshwater areas. All regional councils are responsible for evaluating new proposed aquaculture applications under the Resource Management Act 1991, thus ensuring aquaculture impacts on the environment are controlled/minimized. Although an area-based cumulative system is in place for both marine and freshwater farms, only the latter is integrated with other industries such as agriculture. Regional councils are contactable and records demonstrate enforcement is robust. The final score for Criterion 3 – Habitat is 7.0 out of 10 for marine farms and 9.33 out of 10 for freshwater farms.

Criterion 4: Evidence or Risk of Chemical Use
Despite occasional high mortality events associated with warm-water events and disease, reports and personal communications with veterinarians show antibiotics have not been used on any NZ salmon farms. Chinook salmon have a low vulnerability to external parasites, and similar information sources show pesticides have also not been used. All salmon farms have biosecurity

plans in place, and in 2019, biosecurity best management practices have been formally implemented. Anti-fouling paint was used historically in marine farms (never in freshwater farms), but this practice has been discontinued and replaced by mechanical net cleaning. Other chemicals such as anesthetics and disinfectants are used but are of low direct concern. As such, the final score for Criterion 4 – Chemical use for freshwater and marine farms is 10 out of 10.

Criterion 5: Feed

Feed composition data were provided by the major feed companies for each of the three main Chinook farms in NZ. All three farms (NZKS, Sanford, and MCAS) also supplied their specific production values (e.g., eFCR). For marine farms, the average eFCR was 2.0 and the calculated Forage Fish Efficiency Ratio (FFER) was 1.82 for fish oil, meaning that 1.82 tons of wild fish must be caught to provide the oil required to produce 1 ton of farmed Chinook salmon. The wild fish used in feed are sourced across numerous fisheries worldwide (Peruvian anchovy and Indian oil sardine are the primary species) with an overall sustainability score of -5 out of -10. The Wild Fish Use score for marine farms is 3.62 of 10. There is a minor net edible protein loss of 19%, and a feed footprint (land + ocean area needed to produce one ton of Chinook salmon) of 14.75 hectares (ha). The final combined score for Criterion 5 – Feed for marine farms is 5.06 out of 10.

For freshwater farms, the eFCR was1.65 and the FFER 1.58 for fishmeal, and the fisheries sourced were similar to that of the marine feed, resulting in a Wild Fish Use score of 4.48 out of 10. Freshwater farms have a net protein loss of 42%, and the feed footprint is 14.08 hectares. The final Criterion 5 – Feed score for freshwater farms is 4.74 out of 10.

Criterion 6: Escapes

Chinook salmon were first brought to NZ in the 1870s for the purposes of initiating a commercial fishery, and although this commercial venture failed, Chinook salmon became fully established and now form an important recreational fishery. Fish and Game NZ produces and releases large numbers of Chinook smolt to support this fishery in both the freshwater and marine environment. The salmon farm net pens are vulnerable to escape, and many losses have occurred in NZ, but the established status of the species and purposeful release of Chinook by a non-profit organization (Fish and Game NZ) for recreational purposes mean that escapes are not considered to cause significant additional ecological impacts. Therefore, the final numerical score for Criterion 6 – Escapes is 10 out of 10 for both marine and freshwater farms.

Criterion 7: Disease – pathogen and parasite interactions

While pathogens are naturally present in the marine and freshwater environment and have caused occasional disease outbreaks on a small number of sites (two sites from 2012 to 2015), there has not been significant amplification or outbreak of diseases in the NZ salmon industry. An analysis of disease risks from marine farms in NZ identified five diseases that posed substantial threat/risk which included Rickettsia-like bacteria (NZ-RLO), aquatic birnavirus, amoebic gill disease (*Neoparamoeba perurans/Cochliopodida* sp.), and sea lice (*Caligus* spp.). NZ-RLO and *Tenacibaculum maritimum* have been found to be widespread across marine farms in NZ, but an official investigation identified that mortality events on two sites associated with the disease were most likely a result of multiple factors including unseasonably warm water temperatures and low flow, and reduced feed intake, in combination with NZ-RLO. NZ-RLO has not been detected in wild fish. Though various biosecurity control and management practices are in place in both marine and freshwater farms, Chinook are considered largely resistant to parasites such as sea lice and amoebic gill disease, and academic studies provide additional information supporting the conclusion that pathogens and parasites on farms do not currently significantly infect or affect wild fish populations. Although pathogens and parasites are present in the hydro-electric canals, there have been no disease outbreaks reported on freshwater farms in NZ. With no current reported major outbreak beyond isolated NZ-RLO cases, the inherent risk of disease transfer/amplification from net pens results in a score of 8 of 10 for marine and freshwater farms.

Criterion 8X: Source of Stock – independence from wild fisheries
All farmed Chinook stock (broodstock, eggs, juveniles) are sourced from hatcheries and domesticated populations and therefore entirely independent of wild fisheries. The final score for Criterion 8X – Source of Stock is therefore a deduction of zero for both marine and freshwater farms.

Criterion 9X: Wildlife and Predator Mortalities
Marine salmon farms potentially impact several species of birds and marine mammals that are native to Big Glory Bay and the Marlborough Sounds. There are six potentially impacted species listed by the NZ Department of Conservation as nationally endangered (NZ king shag, black-billed gull, black-fronted tern, bottlenose dolphin, southern right whale and Hector's dolphin). There have been ten dolphin mortalities since 1999 at NZKS sites, with one possible mortality of a Hector's dolphin in 2005 and a bottlenose dolphin entanglement and subsequent mortality in 2010. No reported dolphin mortalities have occurred at Sanford farms, which the company attributes to the absence of predator nets used to reduce seal interactions. There were 16 NZ Fur seal mortalities at NZKS farm sites from 2013 to 2018; Sanford has not reported any seal mortalities.
Three bird mortalities have been reported at NZKS from 2013 to 2018 and NZKS has a king shag management plan and conducts a consensus every three years to ensure interactions do not harm the nationally endangered population. The potential for undetected or unreported mortalities is noted here, but though the risk of entanglements of an endangered species is of concern, the low number of marine mammal and bird mortalities reported in marine farms throughout NZ are considered unlikely to impact the population status of the affected species. The final numerical score for Criterion 9X – Wildlife and Predator Mortalities receives a deduction of –4 out of –10 for marine farms.

Potential predator interactions in freshwater farms are limited to birds. Bird nets and other deterrents are used to reduce predation, but no entanglements or mortalities have been reported in freshwater farms. Although there is also the potential for undetected or unrecorded mortalities, there are not considered to be significant mortalities at freshwater farms, and the final numerical score for Criterion 9X – Wildlife and Predator Mortalities is a deduction of –4 out of –10 for marine farms.

Criterion 10X: Escape of Secondary Species

All of NZ's aquaculture industries move stock around the country and both freshwater and marine Chinook farms are reliant on smolt produced in land-based freshwater hatcheries. A survey of NZ freshwater and marine salmon farmers showed a moderate to high concern for preventing and managing introductions of aquatic plants, other fish species, and microalgae, in addition to bacterial, viral and fungal diseases, and parasites. From the same survey, approximately 70% of freshwater farmers consider it likely or very likely that pests or diseases can enter their farms through stock transfers. Although some freshwater movements occur in the same waterbody, and non-profit stockings for recreational purposes follow the same movement patterns, both freshwater and marine farms are considered to be largely dependent on transwaterbody movements. The tank-based hatchery systems and the biosecurity regulations and management measures offer the potential for high biosecurity, but there is little information available on how effectively these measures are enacted or enforced. Overall, the combination of a high dependence on live animal movements and moderate to good biosecurity practices result in a moderate deduction for Criterion 10X – Escape of Secondary Species of –3.6 out of –10.

Overall, the final score for Chinook salmon farmed in marine net pens in New Zealand is 6.78 out of 10 and for freshwater net pen is 7.87 out of 10 with no Red-ranked criteria. The final ranking for both marine and freshwater net pens is Green and a recommendation of Best Choice.

Introduction

Scope of the Analysis and Ensuing Recommendation

Species
Chinook (King) Salmon (*Oncorhynchus tshawytscha)*

Geographic Coverage
New Zealand.

Production Methods
Marine net pens
Freshwater net pens

Note: This assessment focuses on the three main producers and analyzes marine farms (New Zealand King Salmon and Sanford) separately from those in freshwater (Mount Cook Alpine Salmon) to generate two recommendations for marine and freshwater net pen systems.

Species Overview

Brief overview of the species
Chinook salmon (also known as king salmon) are native to the Northern Pacific Ocean and distributed from central California to Kotzebue Sound, Alaska and from northern Hokkaido, Japan to the Anadyr River in Russia (Groot and Margolis 1991). Chinook salmon are anadromous; they hatch in freshwater, migrate to the ocean as fry, and return to their natal streams as adults to spawn. Chinook die following a single spawning event (semelparous). There are two distinct life-history types: ocean and stream. Ocean Chinook fry migrate to the ocean and remain at sea for 2 to 6 years, while stream-Chinook remain in freshwater for several years before going to sea for 2 to 4 years (Araya et al. 2014). Chinook are largest of the salmon species and can grow up to 45 kg. Their diet consists of larval and adult insects as well as small fish (Groot and Margolis 1991).

Chinook salmon were first brought from California and introduced into NZ for the purposes of commercial harvests in the late 1800s (Grott and Margolis 991). Intensive stocking continued throughout the early 1900s, and though Chinook are established and spawn in regions across southern NZ, the wild population remains limited and no commercial scale fishery exists. Chinook fry were first cultivated commercially in NZ in 1976 and the first experimental salmon marine pen on Stewart Island was established in the early 1980s (NZKS 2016).

Production system
All Chinook salmon cultivated in NZ are reared in tanks in freshwater hatcheries and then transferred to net pen grow-out sites in either freshwater (i.e., 17% of total production) or marine (i.e., 83% of production) environments (Aquaculture NZ 2019). This analysis focuses primarily on the net pen grow-out phase of Chinook in freshwater hydrocanals and coastal waters rather than

the hatcheries. The location and relative national production of the three main freshwater and marine sites farming Chinook salmon are shown in Figure 1.

The hatchery phase lasts 8 months followed by 16 months in freshwater/marine net pens until they reach a harvestable size of 3 to 4 kg (NZKS 2016) (Fischer and Appleby 2017). Net pens are open to water exchange from the waterbodies in which they are sited and are constantly flushed by currents to bring clean, oxygenated water to the fish. This open water exchange also allows the free passage of effluents and pathogens between the net pen and the surrounding environment.

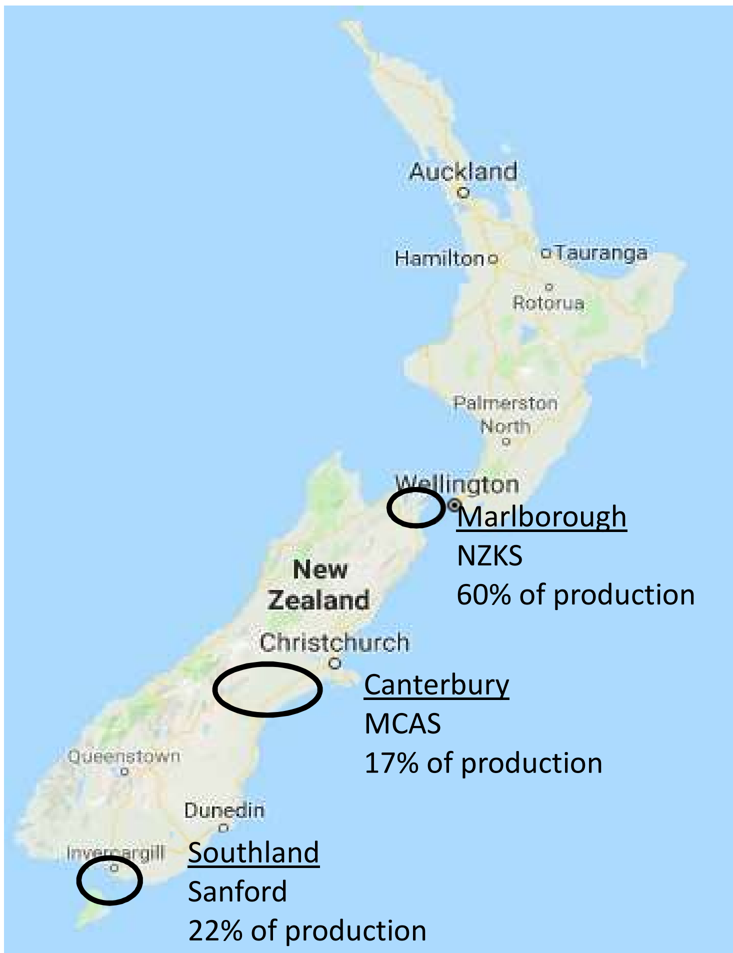

Figure 1: Distribution and contribution to national production of major salmon farms in NZ. Chinook salmon cultivation concentrated in the Marlborough Sounds, Canterbury, and Southland, specifically in Big Glory Bay. New Zealand King Salmon (NZKS), Mount Cook alpine salmon (MCAS), and Sanford were the three farms analyzed in this report. Two small salmon farms not listed/assessed are: Akaroa salmon (Canterbury, marine) and high-country salmon (Canterbury, freshwater). Map is generated from Google maps, with production statistics from (Aquaculture NZ 2019).

Over 80% of Chinook production is marine based with two dominant companies operating in the Marlborough Sounds (NZ King Salmon, hereafter NZKS) and Big Glory Bay/Stewart Island (Sanford Limited) representing 60% and 22% of marine production, respectively.

All freshwater cultivation of Chinook salmon in NZ occurs in hydroelectric canals in the Mackenzie Basin (Salmon NZ 2011) (FAO 2005). These canals are fed by glacial water and were created by damming the three main glacial lakes (Tekapo/Takapo, Pūkaki and Ōhau) and raising water levels of Lakes Tekapo/Takapo and Pūkaki between the years of 1935 to 1985 (ECAN 2018). Canals were built for the purpose of hydroelectricity production, which first began operation in 1935 (ECAN 2018). Freshwater salmon cultivation occurs via net pen, and these pens are anchored to the side of the canals (NZSFA 2011).

Production Statistics

Chinook are the only salmon species grown in NZ, and total production amounted to 14,339 MT in 2018, valued at ~ US$ 157,000,000 (Aquaculture NZ 2019). More specifically, NZKS produces approximately 8,600 metric tons (MT) and Sanford produces 3,400 MT of salmon annually (Aquaculture NZ 2019) (James et al. 2018a). Mount Cook Alpine Salmon (hereafter MCAS) in Canterbury produces the bulk of freshwater Chinook salmon, at approximately 1,700 MT annually (AQNZ 2019). There are two other minor producers, one using marine sites (Akaroa Salmon) and one in freshwater (High Country Salmon).

Chinook production in British Columbia (BC) was 2,346 MT in 2016; thus, the global total is over 15,000 MT (Issac, pers. comm. 2019). However, Chinook salmon is only a fraction of global salmon aquaculture's 2.36 million MT in 2018, of which Atlantic salmon was approximately 2.2 million MT (Mowi 2019). The top salmon producing countries are Norway, Chile, and the UK, particularly Scotland (FAO 2018 b).

Since commercial salmon farming began in NZ in 1983, production has increased steadily and doubled from 2000 to 2016 (Figure 2; FAO 2018). The granting of new permits (i.e., consents) for marine Chinook aquaculture between 2001 to 2011 was extremely limited due to a moratorium on new permits in place from 2001 to 2004, combined with the legal establishment of Aquaculture Management Areas (2004 to 2011) (Fløysand et al. 2016). To promote growth of the industry, the Aquaculture Reform Amendment Act of 2011 was passed, which removed the requirement to locate new marine farms within an Aquaculture Management Area (Fløysand et al. 2016).

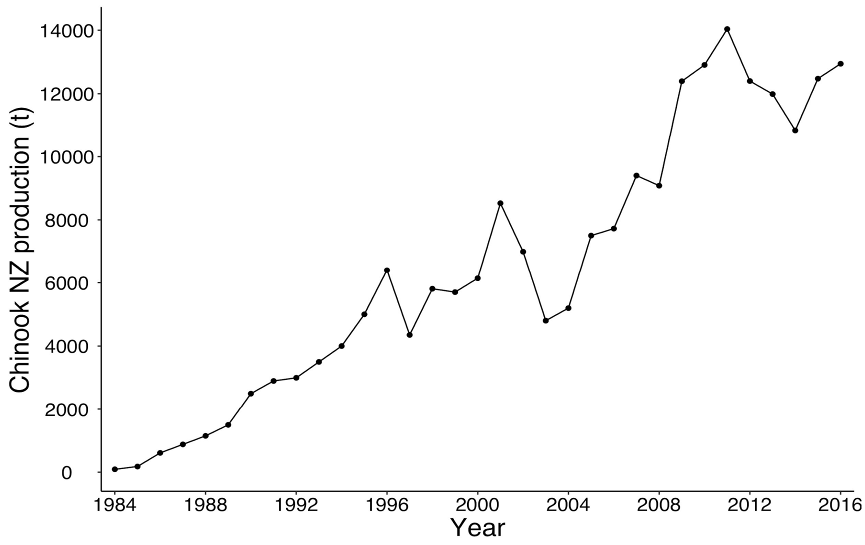

Figure 2: Chinook salmon aquaculture production quantity (MT) in NZ across marine and freshwater production systems from 1984 to 2016 (data from FIGIS 2018).

Import and Export Sources and Statistics

Approximately 30% of Chinook salmon produced in NZ remained for domestic consumption (FIGIS 2018) (Seafood NZ 2018); the remainder is exported to approximately 50 countries with the bulk going to Japan, the US, and Australia (Seafood NZ 2018). In 2017, approximately 49% (2,512 MT) of the exported Chinook was imported into the US (NMFS Fisheries Statistics Division). Imports of Chinook salmon into the US has been increasing since 2014, up from 700 MT during the 2009 to 2014 period (NMFS Fisheries Statistics Division).

Common and market names

Scientific Names	*Oncorhynchus tshawytscha*
Common Names	Chinook salmon
United States	King, quinnat, or spring salmon
Spanish	Salmón real
French	Saumon royal
Japanese	チヌック鮭 (Chinukku sake)

Product forms

Whole fresh and frozen, filets, steaks, smoked, and gravlax.

Analysis

Scoring Guide

- With the exception of the exceptional criteria (8X, 9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rating. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the three exceptional criteria result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Standard that the following scores relate to are available on the Seafood Watch website.

https://www.seafoodwatch.org/-/m/sfw/pdf/criteria/aquaculture/mba_seafood%20watch_aquaculture%20standard_version%20a3.2.pdf?la=en

Criterion 1: Data Quality and Availability

Impact, unit of sustainability and principle

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

Marine and Freshwater Farms

Data Category	Data Quality (0-10)	Score (0-10)
Industry or production statistics	7.5	7.5
Management	10	10
Effluent	7.5	7.5
Habitats	7.5	7.5
Chemical use	10	10
Feed	10	10
Escapes	10	10
Disease	7.5	7.5
Source of stock	10	10
Predators and wildlife	7.5	7.5
Secondary species	7.5	7.5
Other – (e.g., GHG emissions)		n/a
Total	**95.0**	**95.0**

C1 Data Final Score (0-10)	**8.6**	**GREEN**

Brief Summary

A large amount of specific information and data on marine and freshwater Chinook farms are available in New Zealand. The three main companies provided farm- and company-specific data, and further information is available from regional councils, feed companies, environmental regulators, the Global Salmon Initiative, and certification bodies, in addition to the general and NZ-specific academic literature on salmon farming. This assessment acknowledges the potential limitations of company-reported data, but overall the data gives high confidence that the industry and its impacts are understood. The final score for Criterion 1 – Data quality and availability is 8.6 out of 10 for both marine and freshwater farms.

Justification of Rating

Industry and Production Statistics

Due to the relatively small size of the industry, recent total production data were submitted directly by companies. Production information is also published in company reports e.g., (NZKS 2016) (MCAS 2018) and through industry organizations website, such as Aquaculture NZ[2] which also lists the contact information for main salmon farms, hatcheries, and consulting/third party organizations involved with commercial salmon farming in NZ. The AQNZ website also hosts an annual "sector overview" booklet which contains total production and value information).[3] Information on the number of sites, locations,[4] and consent conditions are publicly available on regional council websites across all salmon farming regions,[5] but detailed production data per site is not available. With good (self-reported) company-level data in New Zealand, both marine and freshwater salmon farming receive scores of 7.5 out of 10 for relevant industry and production statistics.

Management and Regulations

Information regarding national, regional, and local laws and regulations and/or industry management measures as well as inclusion of area-based or cumulative impact measures, and implementation of these measures at the individual farms, were readily available. Regional councils[6] make resource consent conditions, regulations, annual reports, enforcement actions, and other relevant material publicly available. Resource consents also include conditions and contact information of the enforcement agency. As a result, both marine and freshwater salmon farming receive scores of 10 out of 10 for availability of management and regulation information.

Effluent and Habitat

Academic papers such as (Price et al. 2015) and NZ-specific studies such as (Keeley et al. 2013, 2014, 2015) demonstrate the general global understanding of water column and benthic impacts of salmon farms. Information on the water quality and benthic monitoring requirements under the Resource Management Act (RMA) of NZ and specified by the regional councils are available for all farms (noting no benthic monitoring requirements for freshwater farms). Environmental monitoring is conducted by independent third parties, and the Marlborough Sounds District Council is the only Council that publishes the reports on their website; MCAS and Sanford provided third-party monitoring data for the purpose of this report. An evaluation of monitoring

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[2] http://www.salmon.org.nz/new-zealand-salmon-farming/production/)

[3] https://www.aquaculture.org.nz/resource-library/general/

[4] Maps: https://maps.marlborough.govt.nz/smaps/;
http://gis.es.govt.nz/landing.aspx;
https://mapviewer.canterburymaps.govt.nz/

[5]Consent conditions: https://www.marlborough.govt.nz/services/property-files-online);
https://www.es.govt.nz/services/consents-and-compliance);
https://www.ecan.govt.nz/data/consent-search)

[6] NZ is divided into sixteen regions, the majority of which are governed by regional and district councils (the top tier of local government), and five are administered by unitary councils, which may perform both roles. For simplicity's sake, the term "regional councils" is used in this assessment, but may refer to district, regional, or unitary Councils.

data published in an Assessment of Environmental Effects (AEE) report for Sanford was also used in this analysis (James et al. 2018a). In addition to farm monitoring requirements, all three regional councils analyzed conduct annual "State of the Environment Monitoring" that includes gathering data on nitrogen levels, chlorophyll *a*, as well as other environmental parameters. For example, Environment Canterbury (ECAN) collects water quality samples at various sites throughout the Canterbury Region. Results of these water quality tests are publicly available on their website.[7] Data availability for benthic and water quality impacts is generally good but understanding far-field impacts and potential cumulative impacts at different sites is still limited. Both marine and freshwater salmon farming have a score of 7.5 of 10 for effluent and habitat data availability.

Chemical Use

Both freshwater and marine farms reported their use of antibiotics or pesticides for this assessment. A list of hazardous material kept onsite at NZKS and MCAS was also provided. NZKS is a member of the Global Salmon Initiative (GSI) and is required to report annual chemical use (the data submitted to GSI are validated by a third party). The use of anti-fouling paint on cages has also been discontinued at the marine (NZKS and Sanford) sites. Freshwater farms were never allowed to use anti-foulant paint because of water quality drinking standards set by the regional council. The marine and freshwater farms assessed here are Best Aquaculture Practices (BAP) certified,[8] and BAP audit reports, including chemical use, were provided, as were statements from veterinarians associated with the marine and freshwater farms. Data availability for Chemical use has been scored as 10 of 10 for both marine and freshwater.

Feed

Feed information was provided by the main suppliers for the largest marine (NZKS and Sanford) and freshwater (MCAS) farms in NZ. This included detailed feed composition information and data on the provenance of marine ingredients. Economic FCR information was also provided by all farms for the purposes of this assessment. Lab-evaluated protein composition of Chinook in freshwater farms was also provided by MCAS. Confidence in the accuracy of feed and the industry supplied values is high; thus, feed data was scored as 10 of 10 for freshwater and marine farms.

Escapes

The introduction of Chinook salmon into NZ for recreational and commercial fishing in the late 1800s is well established, e.g., (NZKS 2016), as is the continued stocking of smolt for the purposes of recreational fishing by Fish and Game NZ, e.g., (Willis 2018). NZKS reports annual escape events on the GSI website. MCAS detects escapement events through regular farm monitoring and procedures require a report to be completed for every escapement detection. These reports were provided for this assessment. Since regular escapement reports are maintained and were

[7] https://www.ecan.govt.nz/data/water-quality-data/wqdetails;
https://www.marlborough.govt.nz/environment/state-of-the-environment-reporting
https://www.es.govt.nz/services/environmental-monitoring/Pages/default.aspx

[8] https://www.bapcertification.org/CertifiedFacilities

provided, and knowledge on the (lack of) potential impacts due to the ongoing stocking is robust, data availability was scored as 10 of 10.

Disease

In general, there have been no major incidences of disease outbreaks in NZ besides mortality events that occurred from 2012 to 2015 at two farm sites in NZ, which are described in a research report commissioned by Ministry of Primary Industries (MPI) (Fischer and Appleby 2017). Publicly available data on disease in NZ is available from OIE (Office International des Epizooties) and quarterly investigation results are available. Various veterinarians for the largest marine and freshwater farms in NZ provided official statements on disease occurrences. A biosecurity plan and disease contingency plan have also been made available from the largest freshwater and marine salmon farm. Studies such as (Diggles 2016) and (Fischer and Appleby 2017) give some confidence that pathogens on farms are not being detected in wild fish to date, and that other pathogens detected on farms are not causing significant risk of diseases in wild fish populations, but overall there is considered to be a limited body of academic literature describing the real or potential impacts on wild fish populations in New Zealand. These factors have led to a disease data score of 7.5 of 10 for marine and freshwater farms.

Source of Stock

Chinook salmon are non-native to NZ and the national government has not allowed importation of broodstock into the country since 1907. Importation of live animals is strongly regulated through the national government. All freshwater and marine farms evaluated in this report source from freshwater hatcheries in NZ and broodstock are not sourced from the wild. Therefore, a score of 10 of 10 for both marine and freshwater farms has been given.

Wildlife and Predator Mortalities

Data concerning interactions between salmon farms and wildlife/predators are available for marine farms. Independent evaluations have been conducted addressing wildlife mortalities as a result of the expansion in 2014 and the current proposed relocation of 6 farms in the Marlborough Sounds. Predator mortalities are publicly documented by NZKS (e.g., press releases and on the Global Salmon Initiative website from 2013 to 2018). NZ Fur seal mortalities at NZKS farms were calculated based on information reported to GSI. An independent evaluation of Sanford farms in Big Glory Bay is available (James et al. 2018a); however, it is possible that not all entanglements are recorded (or reported) and/or correctly identified at all farms. Birds are the only predator/wildlife interaction of concern in freshwater farms, and representatives stated no bird mortalities have occurred. A precautionary score of 7.5 of 10 for predator and wildlife interactions has been given for marine and freshwater salmon farms because of the risk of unobserved or unreported entanglements.

Unintentionally Introduced Species

Locations of hatcheries and sources of animals have been provided by industry and are available in multiple publicly available reports, e.g., (NZKS 2016) and MCAS annual report). All hatcheries are either located in the same or neighboring regional councils as the farm sites, but a biosecurity survey (Sim-Smith et al. 2016) highlighted the risk of introducing secondary species during live animal movements, and therefore helped determine the scale of transwaterbody movements. Substantial information regarding biosecurity regulations and management measures are available, e.g., (MPI 2017), but Sim-Smith et al. indicate some uncertainty in their enactment or enforcement (Sim-Smith et al. 2016). Detailed information of high priority invasive species such as Didymo (*Didymosphena* spp.) was available from NIWA, and from expert personal communication (C. Gilroy, pers. comm. 2019). Overall, there is a good understanding of the risk, although some uncertainty remains; the data score is 7.5 out of 10.

Conclusions and Final Score

Overall, data availability and quality are strong throughout the NZ Chinook salmon industry. There is still some uncertainty around available data to accurately inform the assessment regarding the risk of impacts to habitat/effluent, disease/chemical use, unobserved mortalities, industry production statistics and introduction of secondary species, but both marine and freshwater farms score 8.6 out of 10 for Criterion 1—Data quality and availability.

Criterion 2: Effluent

Impact, unit of sustainability and principle

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

Criterion 2 Summary

Marine Farms

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**6**	**YELLOW**

Freshwater Farms

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**8**	**GREEN**

Brief Summary

Salmon farming companies in New Zealand have considerable variability in their consent requirements (e.g., nitrogen levels, total feed discharge, chlorophyll *a*, and DO and allowable benthic impacts) depending on the location of the farm (in high or low flow areas), the associated regional council, and also the age of the consent. Annual water quality monitering is administered under some consents and the reports are provided to the relevant regional council. NZKS reports are publicly available and MCAS and Sanford provided reports and third-party assessments for the purposes of this assessment.

Regarding impacts beyond the immediate farm area, although available data show no evidence that effluent discharges have substantial impacts beyond the Outer Limit of Effect (OLE) the OLE distances from the net pens are high (300 m and up to 600 m at some sites), and a significant impact (i.e., an Enrichment Scale (ES) of approximately 3 where 1 is pristine) is observed and permitted at 300 m (and up to 600 m at some high flow sites). This indicates some potential for cumulative waterbody impacts, and a precautionary score of 6 out of 10 for marine farms has been set for Criterion 2 – Effluent. Evaluation of the monitoring reports from freshwater farms show general compliance and that water quality parameters outside the allowable zone of effect are similar below and above the farms. Thus, there is little concern that effluent discharges cause or contribute to cumulative impacts at the waterbody/regional scale, and the resulting final score for Criterion 2 – Effluent for freshwater farms is 8 of 10.

Justification of Rating

This criterion applies to effluent effects outside the farm boundary or beyond an allowable zone of effect. Impacts within the farm's boundary, immediate area or allowable zone of effect are addressed in Criterion 3 – Habitat. Although the two criteria cover different impact locations, some overlap is inevitable between them in terms of monitoring data and scientific studies on soluble and particulate wastes. Most information will be presented in this Effluent Criterion with the intent of minimizing (but not entirely avoiding) replication in the Habitat Criterion. Since effluent data quality and availability are good (i.e., Criterion 1 score of 7.5 of 10 for the effluent category), the evidence-based assessment was used for both freshwater and marine farms.

Salmon excrete both soluble and particulate wastes primarily as a result of incomplete digestion and absorption of their feeds. Emissions of dissolved nutrients from aquaculture can lead to increased plankton growth and increased sedimentation of plankton biomass; the increased supply of organic material to the seabed increases oxygen consumption that affects the benthic communities (MPI 2013) (Svasand et al. 2017). There is a substantial body of literature on physical, chemical, and biological implications of nutrient waste discharges from net pen fish farms, including salmon farms, and key recent reviews such as Price et al. (2015) provide a useful summary. Price et al. (2015) conclude that modern operating conditions have minimized impacts of individual fish farms on marine water quality. The effects on dissolved oxygen and turbidity have been largely eliminated through better management and near-field nutrient enrichment to the water column is usually not detectable beyond 100 m of the farm when formulated feeds are used, feed waste is minimized, and farms are properly sited in deep waters with flushing currents. As discussed below, some NZ marine farm sites are located in shallow, low flow areas, and Price et al. also caution that regardless of location, other environmental risks may still face this industry; for example, significant questions remain about the cumulative impacts of discharge from multiple proximal farms potentially leading to increased primary production and eutrophication (Price et al. 2015).

Previously, academic research studying water quality impacts of Chinook Salmon aquaculture in NZ was limited, though recent efforts have been undertaken to address this gap (Broekhuizen and Plew 2018). The primary national legislation governing aquaculture is the Resource Management Act (RMA) that delegates authority to regional councils[9] who are responsible for the planning, managing, and granting of aquaculture sites (known as resource consents) within their boundaries. Regional councils can specify conditions of resource consents to limit the impact of farms on surrounding water bodies (MPI 2013); as such, freshwater and marine farms in NZ have monitoring requirements and water quality and benthic impact limits. If monitoring reports show consent conditions have been exceeded, then a management action may be triggered (MPI 2013). The different consent conditions for the major salmon farming companies

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[9] NZ is divided into sixteen regions, the majority of which are governed by regional and district Councils (the top tier of local government), and five are administered by unitary Councils, which may perform both roles. For simplicity sake, the term regional councils is used in this assessment, but may refer to district,regional, or unitary councils.

are discussed below and consent conditions for all farms are available online.[10] Despite varying resource consent conditions, annual third party monitoring is conducted at all farms, and this evidence is submitted to the Council to ensure that the relevant consent conditions are met.

The impact of salmon farms on the water column and benthic habitat was evaluated for each salmon farming region using either publicly available or farm supplied monitoring reports and regional council monitoring information.[11] In addition to farm monitoring requirements, all three regional councils analyzed conduct annual "State of the Environment Monitoring" (a requirement under the RMA), that includes gathering data on nitrogen levels, chlorophyll *a*, as well as other environmental parameters. For example, Environment Canterbury (ECAN) collects water quality samples at various sites throughout the Canterbury Region. Results of these water quality tests are publicly available on their website.

Marine farms

Consent conditions

The resource consent conditions set by regional councils regarding water quality and benthic parameters for marine farms are summarized in Table 1. These parameters relate primarily to water column impacts, but benthic impacts may also be managed by total feed input limits (full benthic conditions are discussed in a later section). The consent conditions in Table 1 vary across regional councils and between Sanford and NZKS and newer NZKS farms have stricter effluent and benthic parameters than older farm sites (regional councils have generally increased the strictness of their consent conditions, when new applications are made, as impacts of aquaculture have become better understood[12]). The regional councils also set requirements (or approve proposed requirements) for monitoring frequency and monitoring protocols for both salmon farming companies (Table 1) (Bennett et al. 2018a) (James et al. 2018 a).

Third-party monitoring is conducted by Cawthron[13] for NZKS farms and Aquadynamic Solutions[14] for Sanford farms. Water quality parameters collected include chlorophyll *a*, dissolved oxygen (DO), nitrogen (e.g., ammoniac nitrogen, nitrate) (Keeley 2012) (James et al. 2018 a).

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[10] Consent information for each of the three main salmon farm companies can be accessed using the following links:
NZKS - https://www.marlborough.govt.nz/services/property-files-online;
Sanford - https://www.es.govt.nz/services/consents-and-compliance;
MCAS - https://www.ecan.govt.nz/data/consent-search

[11] Monitoring information for each salmon farm included: NZKS publicly available annual monitoring reports and a third-party produced Assessment of Environmental Effects (AEE) report, and a regional analysis of water quality and benthic habitat (Broekhuizen and Plew 2018). Sanford provided annual monitoring reports from 2016-2018 along with a third-party produced assessment of environmental effects report assessing the impact of salmon farming from 1998 to 2016 (James et al. 2018 a, b). MCAS was evaluated using annual monitoring reports from 1993-2018 and monitoring data conducted by Canterbury council.

[12] Sanford was approved for an increase in nitrogen discharge limits for their farms (from 442.752 to 659 t nitrogen/yr.) in 2019. The only consent condition for Sanford farms prior to the new approval was the annual

[13] Information on Cawthron can be found at https://www.cawthron.org.nz/

[14] Information on Aquadynamic Solutions can be found at http://aquadynamicsolutions.net/

An advisory panel evaluating best management practices (BMP) for water quality in the Marlborough Sounds was convened in 2019 to address the need for clear water quality requirements for consent conditions (Elvines et al. 2019); in general, the guidelines and water quality standards from the working group reflect the levels that are in place for recently consented NZKS farms, and these guidelines will be reviewed every 5 years and updated as needed (Elvines et al. 2019). Results from the working group were released in October 2019; no sites at the time of writing have voluntarily adopted the BMP standards; therefore, the BMP water quality standards do not impact scoring here.

Table 1: Water quality and feed discharge consent conditions for NZKS operational sites and Sanford farms. Conditions are discussed in the benthic impacts section (*Denotes consent conditions that cannot be exceeded for more than 3 consecutive months).

Company	Site (Consent expiration)	Maximum feed discharge (mt)	Sampling plan	Nitrogen	DO	Chl-a/Phytoplankton
NZKS	Te Pangu (2036) (High Flow)	6,000	Monthly: water quality Annual: benthic	x < 300 mg/m^3*	x > 70% 250m* x > 90% past 250m net pen edge	x < 3.5 mg/m^3 (trigger)* max 5 mg/m^3 No change to Phytoplankton/HAB
	Clay Point (2024) (High Flow)	4,000	Monthly: water quality Annual: benthic	x < 300 mg/m^3*	x > 70% 250m* x > 90% past 250m net pen edge	x < 3.5 mg/m^3 (trigger)* max 5 mg/m^3
	Otanerau Bay (2024) (Low Flow)	4,000	Annual: water quality and benthic			
	Forsyth Bay (2024) (Low Flow)	4,000	Annual: water quality and benthic			
	Ruakaka Bay (2021) (Low Flow)	4,000	Annual: water quality and benthic			
	Waihinau Bay (2024) (Low Flow)	3,000	No specific monitoring req's. Annual voluntary sampling conducted			
	Waitata Bay (2049) (High Flow)	3,000 (current) 6,000 (maximum)	Monthly: water quality Annual: benthic	< 300 mg/m^3 stations * < 250 m from farm	x > 70% 250m* x > 90% past 250m net pen edge	x < 3.5 mg/m^3* No change to Phytoplankton/HAB
	Ngamahau (2049) (High Flow)	1,500 (current) 4,000 (maximum)	Monthly: water quality Annual: benthic	x < 300 mg/m^3 stations * x < 250 m from farm	x > 70% 250m* x > 90% past 250m net pen edge	x < 3.5 mg/m^3* No change to Phytoplankton/HAB
	Kopāua (2049) (High Flow)	1,500 (current) 4,000 (maximum)	Monthly: water quality Annual: benthic	x < 300 mg/m^3 stations* x < 250 m from farm	x > 70% 250m* x > 90% past 250m net pen edge	x < 3.5 mg/m^3 No change to Phytoplankton/HAB
Sanford	7 sub-farms		Monthly: water quality Annual: benthic	Cumulative discharge of 659 t nitrogen/yr Ammonia: x < 30 µg/L higher than 2015-17 baseline		x < 3.5 mg/m^3 (trigger)* not to exceed 5 mg/m^3

Nutrient waste in water column

Monitoring reports from both companies show localized effects on the water column regarding nitrogen concentrations and nitrogen/feed limits may be exceeded occasionally (e.g., NZKS 2017–2018 exceeded allotted feed limits and Marlborough District Council issued a minor non-compliance). Summer ammonia levels in 2016 to 2018 (0.025±0.018 STD g/m3) at control sites in Sanford farms show no increase compared to samples taken one year after initiation of commercial salmon farming in Big Glory Bay in 1988/89 (0.026±0.004 g/m^3) (Pridmore and Rutherford 1990) (Aquadynamic Solutions 2018). The low flow NZKS sites in Marlborough Sounds represent a "worst case scenario" because the lower water flow tends to lead to greater localized deposition of nutrients in the benthos; thus, it would be expected that the most concentrated impacts from salmon farming activities would occur at the low flow rather than the high flow sites (where nutrients are dispersed at lower concentrations over a larger area of relevance to this Effluent Criterion). Total nitrogen levels were similar at the net pens compared to control sites at NZKS high flow sites in the Tory Channel in 2016–2017 (Figure 3). These NZKS farms are not permitted to exceed nitrogen concentrations of 300 mg/L for more than three consecutive months (Table 1), and monitoring results show compliance where these limits apply. Low flow sites do not require nitrogen to be sampled, and there is concern that effluent impacts are not being adequately captured at these low flow sites. NZKS and Sanford exhibit evidence of localized impacts on water quality for nitrogen concentrations, but these do not correspond to cumulative concerns in the broader waterbody.

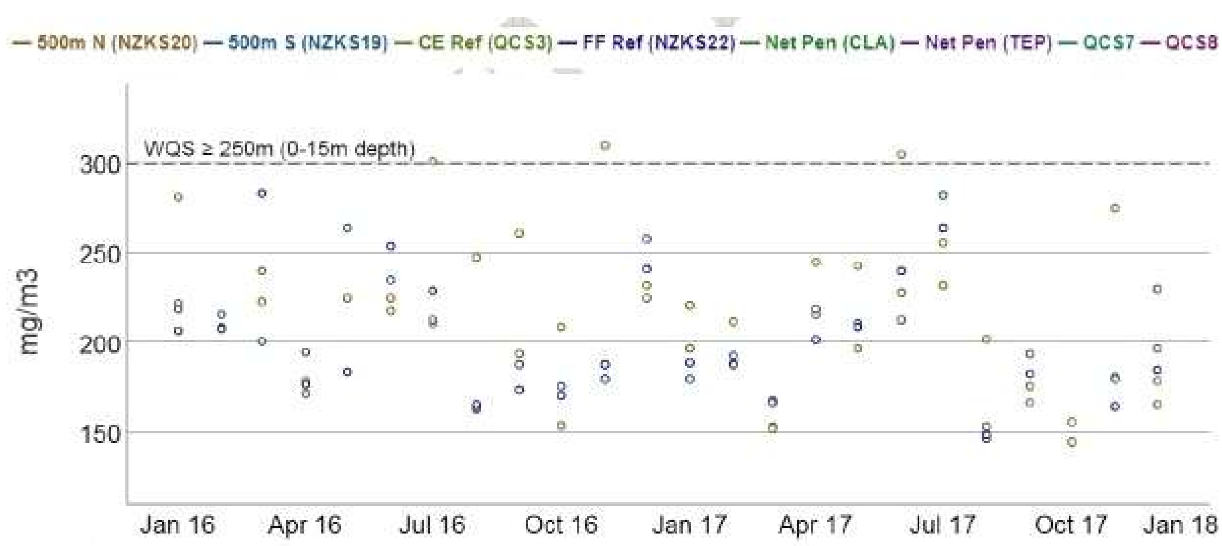

Figure 3: Total nitrogen (TN) concentrations (mg/m^3) in the surface 15m sampling stations in the Tory Channel from January 2016 to December 2017. (NZK refers NZKS monitoring stations and QC (Queen Charlotte Sound) refer to regional council monitoring stations; N (North), S (South) FF (Far-Field); CLA (Clay Point); TEP (Te Pangu). Figure copied from (Bennett et al. 2018).

Chlorophyll a /HAB and Dissolved Oxygen

The nutrients discharged can lead to higher plankton densities (measured as chlorophyll *a*), which may result in harmful algal blooms (HABs). There was a significant HAB event in 1989 in Big Glory Bay resulting in mass salmon aquaculture mortalities; however, there have been no links between HAB events and nutrients released from salmon aquaculture in NZ (MPI 2013).

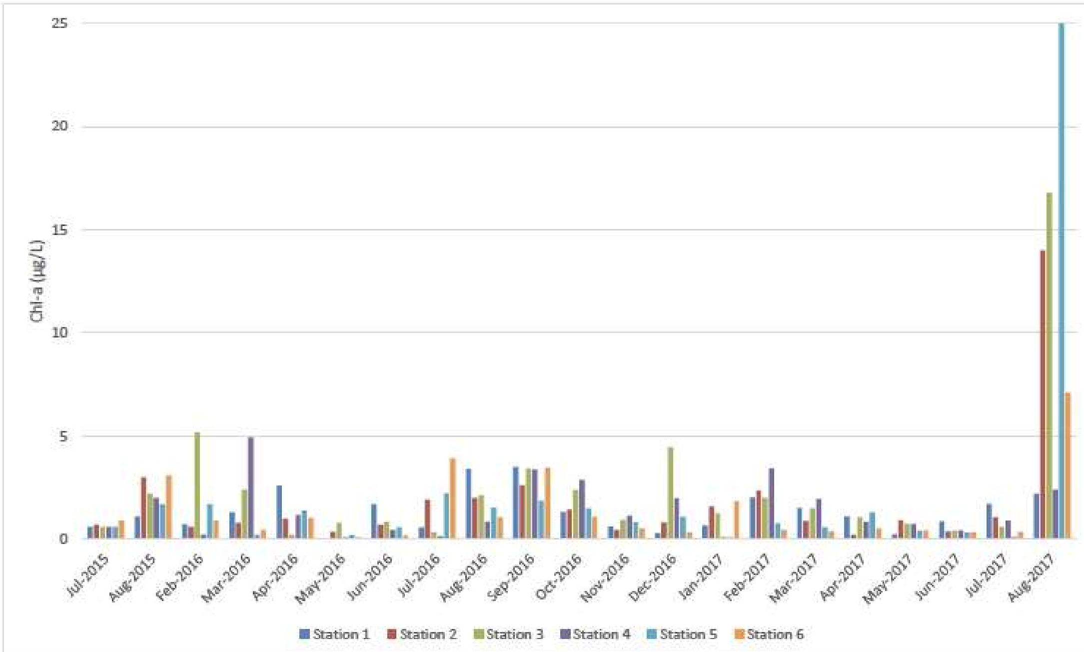

Figure 4: Site-specific chlorophyll *a* concentrations collected as part of Sanford's monthly water quality monitoring program (2015-2017). Station 5 and 6 are located near salmon net pens, and Station 3 and 4 are control sites. Copied from (James et al. 2018a).

Chlorophyll *a* concentrations in Big Glory Bay from the summer of 1988/89 were 4.9 to 5.4 mg/m3, which is similar to concentrations observed in 2016–2017 across control water quality stations and those closer (~250m) to the salmon net pens (Pridmore and Rutherford 1999 in James 2018b; Figure 4). But in August 2017, chlorophyll *a* reached 16.8 mg/m^3; the highest on record (James 2018b; Figure 4). The monitoring report attributed this to larger oceanographic conditions, stating "these levels we suspect are associated with nutrient upwelling in Foveaux Strait which may have pushed nutrient rich waters into the BGB triggering an algae bloom. To the best of our knowledge the bloom appears to be patchy and was nontoxic. No unusual fish mortality was reported in the bay during this time" (Aquadynamic Solutions 2018).

Several NZKS sites require management action if chlorophyll *a* exceeds 3.5 mg/m^3 (maximum 5.0 mg/m3) for over 3 consecutive months (Table 1). These limits align with the water quality standards proposed by the BMP working group (Elvines et al. 2019). Chlorophyll *a* levels have been exceeded at some sites but not for 3 consecutive months. Chlorophyll *a* values from a low flow site show little difference between the net pen, 150 m, and control sites (Bennett et al. 2019). Furthermore, recent analysis of environmental conditions in the Marlborough Sounds found chlorophyll *a* values of 3.5 mg/m^3 were exceeded prior to initiation of salmon farming activity, suggesting the current consent conditions may be overly restrictive based on the background environmental conditions (NIWA 2018). Monitoring results show little evidence of impact on chlorophyll *a* across the marine farming regions in NZ.

Dissolved Oxygen (DO) levels across both salmon farm regions in general remain within acceptable levels, though DO is reduced near salmon net pens. Monitoring data for NZKS show that DO levels have not fallen below the required consent conditions for a period longer than 3 months; but levels have fallen below them for shorter periods at many farm sites. At low flow NZKS sites, DO levels dropped to 6 mg/L at net pen sites in lower mid-water and above the seabed suggesting the farms are causing lower water column DO due to fish respiration and biological activity associated with seabed enrichment (Fletcher et al. 2019). DO levels for Sanford farm sites have generally stayed well above 6 mg/L, but reduced DO levels have occurred directly below farm sites in Big Glory Bay (NIWA 2018). Overall, no wider impacts on DO occurred in the Marlborough Sounds or Big Glory Bay region, though DO is negatively impacted at farm sites.

Benthic impacts

Benthic impacts from salmon farming occur through feces and uneaten food settling on the seabed. Impacts in an area are controlled largely by the settling speed of the particles, the water depth and the current speed; these factors result in a localized gradient of organic enrichment in the underlying and adjacent sediments (Black et al. 2008) (Keeley et al. 2013, 2015). Keeley et al. (2013) describe the major pathways of bio-deposition from a typical net pen salmon farming system; the total particulates leaving the net pen will either dissolve or release nutrients before reaching the seabed, and the portion settling on the seabed in the primary area of deposition, will either be consumed directly by benthic organisms, accumulate and consolidate or be re-suspended and transported to far-field locations. During that transport, further nutrients will be dissolved, diluted, and assimilated, and the remainder will finally settle in far-field locations.

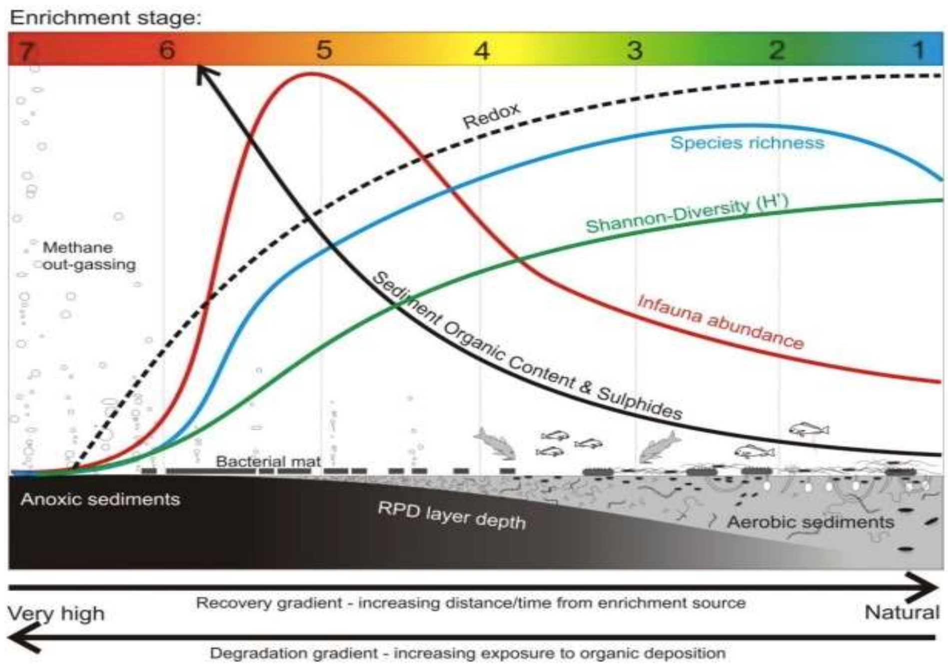

Figure 5: Enrichment Scale depiction with an ES score of seven representing a heavily impacted system a score of one representing a pristine system. (Figure from Bennett et al. 2018).

Salmon farms in NZ must conduct annual benthic monitoring during peak feeding for each farm site. New NZKS high flow sites are required to conduct benthic sampling during the mid to late summer when the greatest benthic impacts would be expected due to relatively poorer environmental conditions (e.g., high water temperatures, increased feeding, more rapid benthic mineralization and therefore decreased oxygen levels). Benthic conditions are monitored by collecting infauna diversity, copper and zinc levels, total organic matter (TOM), particulate organic carbon (POC), and others.

Publicly available monitoring reports from NZKS conducted by Cawthron show general compliance with consent conditions but there were twenty recorded non-compliance instances occurred between 1993 and 2018. All but four were within the consented area of the farm sites (i.e., not outside it, which is of interest to this criterion).[15] There have been incidences of technical non-compliance (e.g., late submission of a report) for Sanford farms but no significant instances of non-compliance (ES 2019).

As stated previously, consent conditions either stipulate (or monitoring is voluntarily conducted) that annual sampling of the benthos is conducted at peak feeding.[16] Cawthron developed a common standard, the Enrichment Scale (ES; Figure 5), for measuring the ecological impact of

[15] Nineteen non-compliances occurred across 8 NZKS sites from 1993 to 2013 and one non-compliance across all eleven sites from 2013 to 2018.

[16] Annual monitoring reports show that occasionally benthic monitoring does not coincide exactly with the month of peak feeding. Discrepancy in timing is typically due to issues with environmental conditions that make sampling difficult (_. Clarkson, pers. comm. 2019).

salmon farming in NZ on the benthic environment in the Marlborough Sounds (Keeley 2012). ES considers variables such as species richness, sediment organic content, and redox potential (Keeley 2012). It results in a single value ranging from 1 (pristine) to 7 (extremely enriched and impacted) (Keeley 2012). In the Marlborough Sounds, consent conditions have been set around the ES scale with permitted levels varying with distance from the net pens. The best management practices (BMP) ES level, as determined by a working group, is below 5 at or directly below the net pens and below 3 at outer limits of effect (MPI 2019). ES levels above 5 are associated with severe declines in diversity and abundance of macrofaunal communities.

Benthic consent conditions for NZKS have been set around the dispersal zone, with conditions set directly below net pens (i.e., zone of maximum effects (ZME) and at the outer limit of effects (OLE) and at reference stations. OLE are set at distances for the total spatial extent of the measurable “footprint” and delineate the outer extent of obvious and measurable effects (Benthic Working Group 2014). OLE distances are set based on environmental parameters of the site such as water flow. The distances of OLE for NZKS sites range from 150 m from the net pens edge for low flow and between 200 and 600 m for high flow sites. OLE distances are set specific to the farm site based on environmental characteristics. A gradient of reduced impact with increasing distance from the net pen is expected. To measure this gradient, intermediary and outermost OLE values are set. The outermost OLE ES value is ES <3.0 (with 600 m the greatest outermost distance across any farm site) and the intermediary is at ES <3.7 (around 300m).

As with water quality consent conditions, requirements vary across NZKS farms with older consents requiring ES scores at or below 6 directly below net pens and new farms with ES values <5. NZKS has only formally adopted the BMP benthic requirements of ES <5 on two of their older farms (Te Pangu and Clay Point), but not for the low-flow sites. NZKS has agreed to implement BMP requirements on low-flow sites by 2024. Impacts directly below net pens are discussed in greater detail in Criterion 3 – Habitat. At NZKS low flow sites, benthic samples are taken from at least two control sites and at 50 m, 100 m from the net pen and directly below the pens (whether fallow or active). Sampling protocol follows BMP and varies across high and flow sites based on depositional modeling exercises and differ for the high-flow sites (MPI 2019).

Over twenty years, all but four of the twenty technical non-compliances received by NZKS have occurred within the farm’s consented area. Both Sanford and NZKS farms show significant benthic impacts within farm boundaries, which is discussed in Criterion 3 Habitat. At low-flow sites, ES values are still slightly elevated at 50 m from the net pen but are similar to control sites at 100 m distance. High-flow sites are meeting BMP practices for the outer limit of effects (OLE, 150 to 600 m from net pen) level of ES 3.7 or lower (Figure 6). In the Marlborough Sounds, much of the seabed is naturally enriched with values of ES 2-2.5 (BMP working group 2014). For Clay Point, the OLE stations are 300 m from the net pen and monitoring results show a moderate level of enrichment at these distances and species richness and diversity is usually lower than reference station (Figure 7, BMP Working Group 2014).

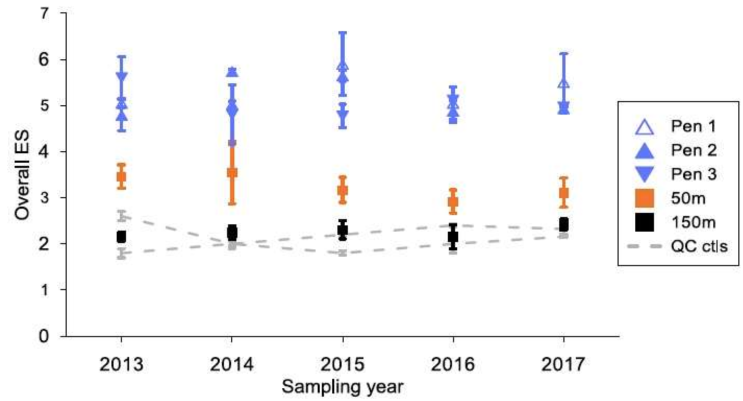

Figure 6: Time series of average overall ES score (± SE [or 95% CI in 2015 to 2017]) at the Otanerau farm monitoring stations from 2013 to 2017 (Graph copied from Fletcher et al. 2018.).

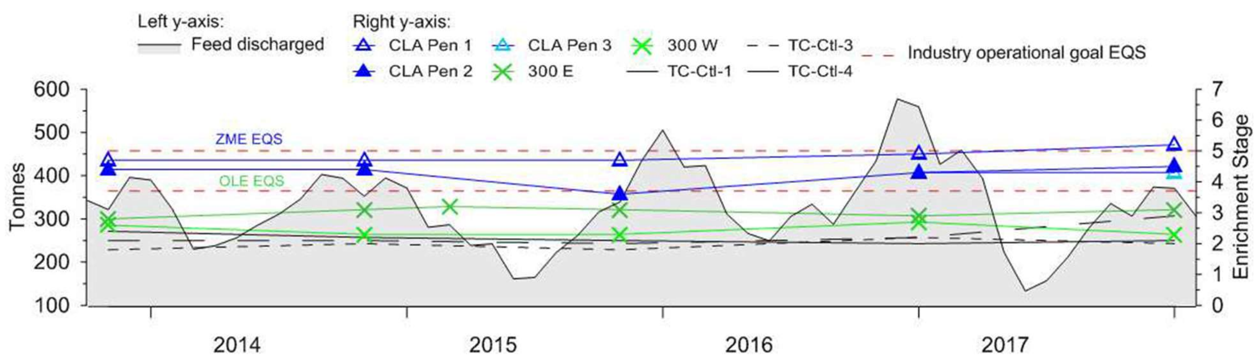

Figure 7: Time series of monthly feed discharge (tonnes) and average Enrichment Stage (ES) score for the last five years of annual monitoring at the Clay Point Bay (CLA) salmon farm. ES scores reported are averages for each station, and relevant Tory Channel reference stations. The best practice environmental quality thresholds for the zone of maximal effect (ZME, ES 5) and outer limit of effects (OLE, ES 3.7) are shown as red dashed lines. Feed data were provided by NZ King Salmon. Copied from (Bennett et al. 2018b).

Sanford samples benthic parameters at each of the salmon farm leases under the net pen and 50 m and 100 m from the site boundary as well as at two control stations (Aquadynamic Solutions 2018). Benthic consent conditions for Sanford farms are not based on ES; instead, acceptable impacts 10 m distance from net pens (i.e., within the ZME) are set that include limits on bacteria (i.e., Beggiatoa) coverage, required levels of biodiversity, and specify that the diversity/abundance must be maintained at levels “that allow for sustained farm waste assimilative capacity and sufficient seabed recovery to support a farm rotation cycle with a fallowing period of not less than 5 years” (Environment Southland Consent).

Enrichment below farm sites occurred at Sanford farms but improved within 100 m of the net pens with benthic conditions similar to control levels (James et al. 2018b). Organic matter and total organic carbon levels in 2018 for a representative farm site were similar at 50 (i.e., 338_50

– see Figure 8) and 100 m (i.e., 338_100) from Sanford farms but were highly elevated below farms (i.e., 338_F) (Figure 8). Species diversity improved greatly at 50 m distance across the three sites, although it is markedly below the diversity at control sites (Figure 9). Overall, although there is improvement in benthic conditions as distance increases from the farm, impacts can still be detected from far distances (e.g., 300 m from net pens).

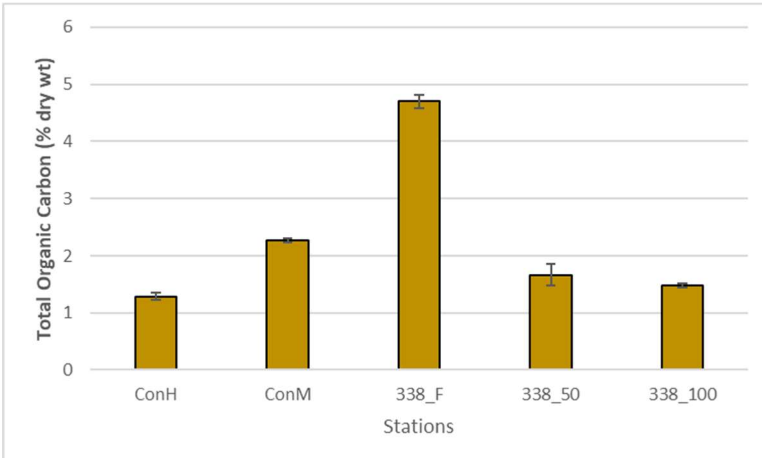

Figure 8: Sanford total organic carbon samples from the area covered by salmon station 338_F (net pen), 338_50 (50 m distance), 338_100 (100 m distance) and at the two control stations (ConM and ConH) (Mean ±1 SE, n=3.). Figure copied from (Aquadynamic Solutions 2018).

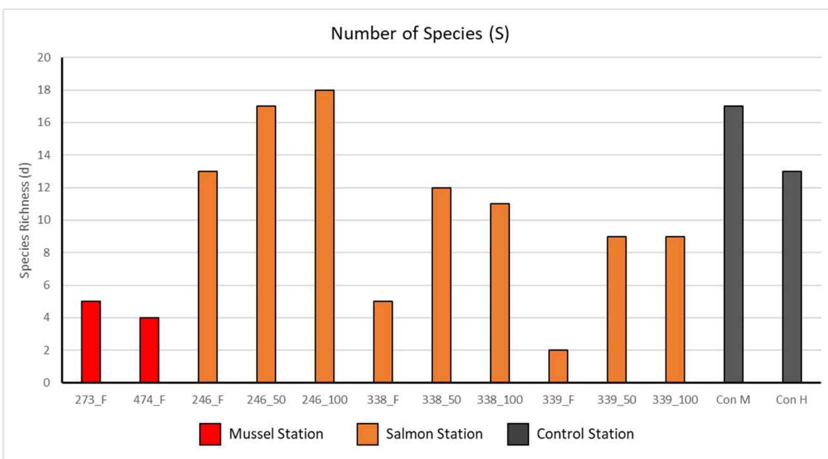

Figure 9: Mean number of species/core (S) from sediments at all sampling stations for Sanford's 2018 annual monitoring results. Figure copied from (Aquadynamic Solutions 2018).

Regional Council Monitoring

Regional councils also undertake annual water quality monitoring in addition to monitoring conducted by industry and this information is released in annual reports. There is no evidence linking any changes in water quality to salmon farming throughout the major marine farming regions in NZ. Although an analysis of water quality throughout the Marlborough Sounds from 2011 to 2018 found suspended solids and nitrate have increased over time and ammonia has dropped slightly, the cause of these changes was not determined (Broekhuizen and Plew 2018). Research shows that since European settlement there has been a significant increase in sediment inputs from land-use which have caused significant ecosystem effects over time, but it is unknown if salmon farming has also contributed to the increase in suspended solids or nitrates (Handley et al. 2017). The report indicated that water quality consent condition parameters established for NZKS are in relative alignment with background levels, and may be overly restrictive in some instances (i.e., chlorophyll *a*) (Broekhuizen and Plew 2018).

The BMP water quality report is expected to be released in 2019 but was not available during the writing of this report and therefore was not considered in scoring.

Conclusions and Final Score—Marine farms

At a cumulative level, regional monitoring has found that effluent discharges do not cause or contribute to cumulative impacts in the water column at the waterbody/regional scale across marine salmon farming regions in NZ. Furthermore, the water quality and OLE benthic parameters for new resource consents for NZKS and Sanford farms further reduce concern of cumulative or regional level impacts. However, the OLE values for NZKS are set at large distances, and though the impacts at 30 m will be much more severe than those at 300 m, a significant impact (i.e., ES of approximately 3) is observed and permitted at this distance (and up to 600 m at some high flow sites) from the net pens. The relatively far-field potential benthic impacts (i.e., up to 600 m at ES <3), compared to control sites, are a concern. While data show no evidence that effluent discharge impacts beyond OLE values as determined by regional councils, there is potential for cumulative benthic impacts at the waterbody or regional scale because of the large distances of these OLEs compared to other salmon farming regions. Thus, a precautionary score of 6 out of 10 for marine farms has been set for Criterion 2 – Effluent.

Freshwater Farms

As with marine farms, freshwater farms are permitted through resource consents granted by regional councils, and ECAN has granted all the consents for commercial freshwater salmon farming in the Mackenzie Country of NZ. All aquaculture operations are restricted to the Haldon Zone or the Valley and Tributaries Zone (LWRP Section 15B4.8). The Canterbury Land and Water Regional Plan (2012) operates at a basin-wide management perspective and regulates the total allowable input of nitrogen into the basin across the farming, aquaculture, and other land-use industries. New aquaculture consent applicants must prepare an Aquaculture Environment Plan and identify the mechanism for monitoring nitrogen discharge to ensure they will not exceed the annual value allotted to the user group. The Haldon zone where MCAS is located receives nitrogen and phosphorus from land-based farming, aquaculture, and community users and the nitrogen load limit is capped at a release of 737 mt/year for all users, with the aquaculture-specific load limit set at 185 mt/year (Canterbury LWRP, Table 15b) (R. Ramsey, pers. comm. 2019). These limits on nitrogen discharge for aquaculture users are intended to control risk of cumulative impacts of aquaculture within the cumulative impacts of all other users.

ECAN has set consent conditions for MCAS requiring monitoring of suspended solids, ammonia-N, 5-day biochemical oxygen demand (BOD), nitrate, nitrite, total nitrogen, total phosphorus and total mercury. Currently, only 4 of these 8 parameters have stated thresholds for salmon farming: BOD 2 mg/L, ammonia-N 0.1 mg/L, nitrate 11.3 mg/L and total mercury 0.002 mg/L. A total daily discharge of 822 kg of contaminants (restricted to feed, fish excreta, and chloramine-T) is permitted. Remaining parameters are assessed at the regional level and the collected data is used to inform management for the entire drainage area (ECAN 2018).

Three of these water quality metrics (i.e., total phosphorus, total nitrogen, chlorophyll *a*) are used to estimate Trophic Level Index (TLI) (Burns et al. 2000). TLI is used throughout NZ to measure the nutrient status of lakes (Burns et al. 2000). Consent trigger levels for TLI have been set and include both early warning (TLI 3.75) and official trigger levels (TLI 4.0) (ECAN conditions, consent # CRC155604). When early warning trigger levels are reached, a report is provided to the regional Council and actions to achieve recommendations in the report must be taken if the farm is found to be the cause/contribute to these levels. Requirements for the report are included in the consent conditions.

Consent requirements for MCAS specify the frequency that samples of canal water must be taken for the different regions where salmon cultivation is permitted. The frequency of monitoring differs across MCAS sites, ranging from bi-annual to monthly sampling, with sampling requirements dictated by consent conditions. Older consents specify less frequent monitoring. Water quality samples are typically taken above, at, and below the farm, though the exact monitoring protocol differs across farms. The results of all monitoring information are required to be submitted to ECAN within 10 days of receiving the results. MCAS also undertakes voluntary sampling of certain water bodies (e.g., Ohau C camping ground) as well as water quality parameters (e.g., *E. coli*) which are not produced by the farms but the regional council is interested in tracking at a basin level (R. Ramsey, pers. comm. 2019). Information analyzed in this report includes monitoring data for all sites from 2013 to 2018, as well as historical data provided by MCAS from 1993 to 2011 for two farm sites. As the Benmore farm was not purchased until 2016, only data from 2016 to 2018 was analyzed at these farm sites. Monitoring of mercury is no longer required since ECAN determined that mercury levels were consistently low to preclude necessary monitoring.

Water quality data

Overall, water quality across all freshwater farm sites for nitrogen (ammonia, nitrate), 5-day BOD, total suspended solids (TSS), and mercury show strong compliance, with levels staying well below consented levels. Table 1 summarizes all instances of non-compliance as well as average and peak measurement values from years 1993 to 2018. The only instances of non-compliance occurred for ammonia (2007 and 2013), and mercury (2009) when the annual required mercury feed analysis was not provided to ECAN. In all instances of non-compliance, the proceeding years' water quality samples indicate full compliance.

Table 2: Summary of water quality monitoring results for Mount Cook Alpine Salmon (MCAS) from 1993 to 2018. Only the water quality parameters with set consent levels are reported. Data from publicly available and farm representative-provided monitoring reports.

Parameter	Consent level	Non-compliance
5-day BOD	2 mg/L	Never
Ammonia	0.1 g/m3	2007 reached 0.15 g/m3 2013 reached 0.2 g/m3
Nitrate	11.3 mg/L	Never
Total Suspended Solids	822 kg/day	Never exceeded 822 kg/day 1998–2000 TSS greater below than above farm
Mercury	0.002 g/m3	2009 Failure to submit report No longer required to monitor

Monitoring results show no to minimal difference in water quality above, at, or below the farm, indicating that farms within the Mackenzie Basin are operating in accordance with consent conditions and are not affecting water quality in the region. The most recent results provided for water quality measurements (from 2018) show full compliance with levels remaining substantially below consent requirements across all locations (i.e., above, at, and below the farm).

At the regional level, ECAN collects water quality samples at various sites throughout the Canterbury Region. Data from 1991 to 2018 at a site in Lake Tekapo (an associated canal), the location of one of MCAS farms, shows similar water quality parameters from 2004 to 2018. For example, total nitrogen (mg/L) readings in 2018 and 2004 were 0.031 and 0.055, respectively.

Conclusions and Final Score – Freshwater farms

Despite releasing all effluent from the farming operation, monitoring data show that water quality is similar above and below the farm. Thus, there is little concern that effluent discharges cause or contribute to cumulative impacts at the waterbody/regional scale. As a result, the final score for Criterion 2 – Effluent for freshwater farms is 8 of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

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

Criterion 3 Summary

Marine Farms

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		7
F3.2a Content of habitat regulations	4	
F3.2b Enforcement of habitat regulations	5	
F3.2 Regulatory or management effectiveness score		8.0
C3 Habitat Final Score (0-10)		**7.0**
Critical?	NO	**GREEN**

Freshwater Farms

Habitat parameters	Value	Score
F3.1 Habitat conversion and function		10
F3.2a Content of habitat regulations	5	
F3.2b Enforcement of habitat regulations	4	
F3.2 Regulatory or management effectiveness score		8.0
C3 Habitat Final Score (0-10)		**9.33**
Critical?	NO	**GREEN**

Brief Summary

Marine farms in NZ are located in coastal inshore sub-tidal areas. Annual monitoring results from 1998 to 2016 show that high enrichment may occur within the immediate farm area, particularly in shallower and/or lower flow locations, but further research indicates that in most cases, these impacts are rapidly recoverable. Freshwater farms are located in hydroelectric canals previously constructed for energy generation purposes, and there are not considered to be any further impacts on habitats or their ecosystem services as a result of construction or operation of the farms.

National legislation in NZ guides decisions around sustainable development of the coastal and freshwater areas. All regional councils are responsible for evaluating new proposed aquaculture applications under the Resource Management Act of 1991, thus ensuring aquaculture impacts on the environment are controlled/minimized. Although an area-based cumulative system is in place for both marine and freshwater farms, only the latter is integrated with other industries such as agriculture. Regional councils are contactable, and records demonstrate enforcement is robust. The final score for Criterion 3 – Habitat is 7.0 out of 10 for marine farms and 9.33 out of 10 for freshwater farms.

Justification

As discussed in the Effluent Criterion, there is inevitably some overlap with the Habitat Criterion as the source of the impacts for both is the same (i.e., uneaten feed and fish waste). The Seafood Watch criteria assess the environmental impacts of these wastes as follows:

- The previous Effluent Criterion (C2) assesses impacts of both particulate and soluble wastes *beyond* the immediate farm area or a regulatory AZE.
- This Habitat Criterion (C3) assesses the impacts of primarily particulate wastes directly under the farm and *within* a regulatory AZE.

Factor 3.1. Habitat conversion and function

The operational impacts on the benthic habitats below the farm and/or within an Allowable Zone of Effect (AZE) can be profound, although the floating net pens used in salmon farming have relatively little direct habitat impacts. Intensive net pen fish farming activities generate a localized gradient of organic enrichment in the underlying and adjacent sediments because of uneaten food and feces and can strongly influence the abundance and diversity of infauna communities. The area under the net pens, or within the regulatory AZE, are profoundly impacted and now relatively well understood (Black et al. 2008) (Keeley et al. 2014) (Keeley et al. 2015).

Marine Farms

Marine salmon production occurs in coastal inshore sub tidal areas, generally over muddy or sandy bottoms, with some farms located in shallow, low-flow, areas (MPI 2013). As described in Criterion 2 – Effluent, most marine farms have consent conditions for allowable impact on the benthos. Only newer NZKS sites have any consent conditions around acceptable levels of zinc or copper in benthos within the farm boundary, e.g., Waitata Bay and Te Pangu (Bennett et al. 2018). NZKS benthic consent conditions, applicable to some of its farms, are based on the Enrichment Scale (ES), with BMP levels set under at the net pens at ES 5 to manage impact on the diversity and abundance of marine life (Benthic Working Group 2014). Annual monitoring reports show older NZKS sites located in low-flow locations exceeded the ES 5 BMP level 12 times from 2013 to 2018, but have remained within the ecological quality standards of an assumed consent level of ES 6 of “excessive enrichment.”[17] Benthic impacts for Sanford sites are controlled through a cumulative nitrogen discharge allotment and recently instated limits on Beggiota coverage, and infauna species diversity at 10 m distance from net pens. Annual benthic monitoring is conducted at each site during peak feed discharge, though as stated in Criterion 2, there are no timing requirements for monthly water quality samples.

The combined results of NZKS and Sanford benthic monitoring show that there can be intensive seabed enrichment directly below the net pens. Benthic conditions at Sanford sites from 1998 to 2017 show high enrichment and low species diversity directly under net pens (James et al. 2018a; Figure 8; Figure 9); for example, both NZKS and Sanford farms have recorded incidences of Beggiota-like patches below net pens. As discussed in Criterion 2 – Effluent, NZKS had 20 recorded technical non-compliances from 1993 to 2018 with all but 4 of these within the consented area of the farm sites. Low flow NZKS sites have ES values between 5 and 6, while high flow sites are typically ES <5 (Figure 6; Figure 7), and across six of the NZKS farm sites located in areas of low flow, BMP for ES levels have been exceeded 12 times. These are not technically considered non-compliance incidences since consent requirements stipulate ES levels <6 below net pens. The latest non-compliance incident for NZKS was a result of exceeding ES 5 directly below the net pen (Clay Point 2017; Figure 7). An alert response was triggered, requiring NZKS to provide a written management response intended to reduce the level of seabed enrichment. Non-compliance has been historically corrected by implementing recommendations from Cawthron from annual reports as well as through voluntary efforts to increase compliance.

With the NZKS low-flow farms, the industry has identified that it will be difficult to achieve BMP benthic levels (i.e., ES <5) while maintaining current production levels (NZKS 2016). As of February 2019, there is a proposal awaiting a final decision by MPI to relocate 6 existing low-flow farm sites to different areas in the Marlborough Sounds of high-flow sites. An advisory panel has recommended the relocation of 3 of 6 sites after consideration of the full suite of issues (environmental, social, economic and cultural) required under the Resource Management Act (MSAP 2017). The relocation of sites is not evaluated in this report, since no decisions have been made.

Zinc and copper

Heavy metals, such as copper (used in antifouling paints and net treatments) and zinc (used as a mineral supplement in feeds) can have an impact on organisms beyond the farm site (Burridge et al. 2010). As mentioned in Criterion 4 – Chemical Use, copper antifouling paints are no longer used in any salmon farms (since 2011) for NZKS, but zinc will continue to be a component of the feed.

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[17] The environmental condition associated with ES 6 is classified as excessive enrichment characterized as a transitional stage between peak abundance and azoic (devoid of any organisms). For older NZKS consents, the ecological quality standards in the consent do not set precise parameters for allowable enrichment stages, though Cawthron has “interpreted the conditions in a quantitative manner using the ES values for consented zones” (Fletcher et al. 2019). This assessment reports ES values as they are interpreted by Cawthron as a proxy for compliance with the consent conditions.

As described in Criterion 2 – Effluent, copper and zinc are monitored annually, either due to consent requirements or voluntarily, across all NZKS and Sanford sites. ANZECC guideline thresholds are used to gauge possible biological effects (ANZECC 2000). The guidelines specify values where concern of biological effects may occur (i.e., “high values”) and values considered trigger levels (i.e., “low values”)[18] (ANZECC 2000). Low and high values for copper are 65 mg/kg and 270 mg/kg, while those for zinc are 200 mg/kg, and 410 mg/kg (ANZECC 2000).

Annual monitoring results from NZKS sites and Sanford’s farms show frequently elevated levels of copper and zinc directly below net pens with a limited spatial extent (Morrisey 2016) (Fletcher et al. 2018) (James et al. 2018a; Figure 10 for NZKS). Zinc and copper levels are greater at low than high flow sites due to lower dispersal from weaker currents (Fletcher et al. 2018). From 2005 to 2017, the “low” copper levels of 65mg/kg were consistently exceeded at NZKS low flow sites, and certain low flow farms (e.g., Otanerau), exceeded ANZECC high levels (Figure 10). The large proportion of copper beneath the net pens is bound in particulate form and therefore, it has limited bioavailability and limited ecological impacts are expected (Fletcher et al. 2018). The reason for the spike in copper values, following termination of its use as an anti-foulant is unknown (Figure 10). Sanford monitoring results from 2012 to 2015 show copper and zinc exceed ANZECC high levels below net pens, though copper and zinc levels are within ANZECC-low thresholds 100 m from farm boundaries (James et al. 2018a). Copper levels are projected to decline with time, given the stoppage of its use as an anti-foulant for both NZKS and Sanford. Zinc will remain a component in salmon feed and continued BMP monitoring will be required to determine the quantity of zinc accumulating in the benthos directly below net pens. Figure 10 shows there is no apparent pattern of accumulation of zinc over the 2005 to 2017 data period across the four sites, yet retro-active actions to reduce zinc accumulation may be needed.

[18] ISQG–Low refers to a 10% probability that a significant toxicity measure will occur in sensitive species, while ISQG-High refers to a 50% probability of this occurring (Hopkins 2019).

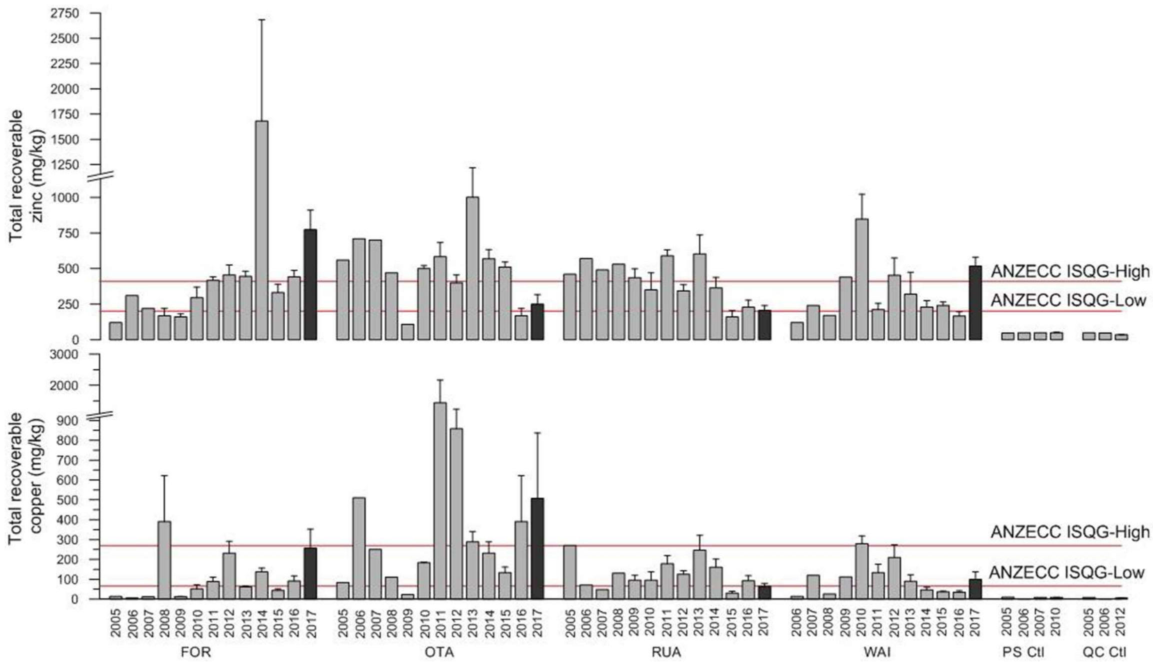

Figure 10: Comparison of the last 13 years of annual monitoring of average sediment total recoverable copper and zinc concentrations beneath the four low-flow operational NZ King Salmon farms and two reference stations (PS = Pelorus Sound, QC = Queen Charlotte). Bars represent averages (± SE). Red lines indicate respective ANZECC ISQG-High and -Low trigger levels. Note; the 2015 metals results are not directly comparable to other years due to the methodological differences in 2015 (only <250 µm grain size fraction analyzed). 2017 bars are a darker grey to identify them as the most recent data. Copied from (Fletcher et al. 2018).

Recovery of benthic habitats

Despite high sediment enrichment, research shows benthic habitats can recover rapidly following fallowing, though this depends on environmental factors and the level of impact (Borja et al. 2009) (Keeley et al. 2014). Several studies have investigated length of recovery for benthic communities following cessation of salmon farming activities in NZ (Keeley et al. 2014). Benthic community recovery occurred rapidly within the first 2 years of fallowing, and full functional recovery (i.e., ecosystem function is re-established, but not necessarily with the same communities that were present pre-impact) was seen after 4 to 5 years (Keeley et al. 2014). For one site (i.e., Forsyth Bay), ecological and chemical recovery was significant 6-months into fallowing; however, resuming salmon farming led to a rapid deterioration of the benthos resulting in anoxic conditions within 3 months (Keeley et al. 2015). The most recent third-party monitoring report (conducted in 2017) found that sediment conditions have remained poor at this site (despite fallowing), and did not recommend re-stocking, even though ES levels are currently low enough to be in compliance with consent and BMP guidelines (Fletcher et al. 2018).

The cumulative spatial extent of marine salmon net pens in NZ is minimal, especially when compared to major salmon producing countries such as Chile and Norway, and farms are also sited to avoid areas of high ecological value. Overall, despite the substantial impacts in the immediate farm area during production, evidence shows recovery of benthic communities can occur within 5 years after fallowing, demonstrating that benthic impacts are not irreversible. Given the potential recovery, the functionality of benthic habitats within the AZEs of Chinook salmon farm sites is considered to be maintained but moderately impacted, and the score for Factor 3.1 for marine farms is 7 out of 10.

Freshwater farms

All freshwater cultivation of Chinook salmon in NZ occurs in hydroelectric canals in the Mackenzie Basin fed by glacier water (Salmon NZ 2011) (FAO 2005). These canals were built specifically for the purpose of hydroelectricity production prior to the aquaculture farms and occur in grassland habitats. The latest monitoring reports from MCAS showed full compliance with water quality parameters determined by the resource consents (reports provided by MCAS). Due to the manmade nature and high-water flow rates of the canals, benthic habitat impacts are not monitored and farm representatives state that the benthic impacts around the farm are minimal to none (T. Bradley, pers. comm. 2019) (B. Blanchard, pers. comm. 2019).

Given that the freshwater farms are located in manmade habitats (constructed for purposes other than aquaculture) and have no further impact on either the contracted habitat or the surrounding grasslands, the freshwater sites receive a score of 10 out of 10 for Factor 3.1.

Factor 3.2. Farm siting regulation and management

Ecosystem impacts are driven largely by the cumulative effects of multiple farms in a location, habitat type, region or a country, and on the distance of separation between farms, connectivity, and overall intensity of aquaculture practices. Factor 3.2 is a measure of the presence and effectiveness of regulatory or management measures appropriate to the scale of the industry, and therefore a gauge of confidence that the cumulative impacts of farms sited in the habitats declared in Factor 3.1 above are at appropriate spatial scales.

<u>Factor 3.2a: Content of habitat management measures</u>

The main policies governing aquaculture in NZ are the national legislation Resource Management Act of 1991 (RMA), the NZ Coastal Policy Statement (NZCPS 2010) and regional coastal plans. Within these policies, regional councils set consent conditions described in detail in the Effluent Criterion. There have been several changes to the regulatory regime for aquaculture under the RMA. For some years (2004 to 2011), new marine farms could only be located within Aquaculture Management Areas (AMAs), as specified in regional coastal plans. However, this requirement was removed in 2011, and marine farms can now be located outside AMAs. Applications are assessed by regional councils within the legal, policy, and planning framework set out above.

Any new farm applications or changes to existing consent conditions require:

1. a resource consent;
2. an environmental impact analysis (i.e., assessment of environment effects; AEE) attached to the resource consent application; and
3. an evaluation of their impact on fishing (i.e., undue adverse effects test) (not required for a change to an existing consent).

The AEE must assess the actual and potential effects on the environment, how any adverse impacts can be avoided, remedied or mitigated, and how impacts can be controlled and whether/how they can be monitored (MPI 2006). Aquaculture applications are almost always publicly notified, and this enables the local community to participate in the decision-making process (Sanford Limited 2017) (MWH 2017). In addition, AEEs for newly proposed consents or alterations to existing resource consents often include modeling scenarios to determine the expected impact that increased aquaculture activity may have on the environment (James et al. 2018b).

The NZ Government is drafting a national environmental standard for marine aquaculture (*NES: Marine aquaculture*),[19] under the Resource Management Act 1991 (RMA) to set national rules that replace regional council rules. The proposed *NES: Marine Aquaculture* standard seeks to provide a more efficient and certain consent process for managing existing marine farms within environmental limits, and implement a nationally consistent framework for biosecurity management on all marine farms. Since the NES: Marine Aquaculture standard was not implemented at the time of writing, it is not evaluated here.

Regional scale management – Cumulative impacts
The RMA provides for the management of cumulative impacts through regional council planning, consenting, and monitoring. The section below analyzes policies of regional councils for marine and freshwater farms.

Marine Farms

There are several policies in place at the regional level in Southland and the Marlborough Sounds concerning the regulations and processes for expansion of aquaculture. The main management tool for aquaculture in Southland is the Regional Coastal Plan, with Chapter 15 guiding aquaculture development in the region (Southland Regional Coastal Plan 2013).[20] The Marlborough District Council developed a Regional Policy Statement (MRPS) in 1995, which directs that "allocation of space for aquaculture will be based on marine habitat sustainability, habitat protection, landscape protection, navigation and safety, and compatibility with other adjoining activities." Both Southland and Marlborough Sounds have established specific AMAs (or aquaculture zones) within their jurisdiction. For Southland, aquaculture has been zoned as only able to occur in Big Glory Bay and is prohibited in areas of high conservation, ecological, and culturally important regions (Southland Regional Coastal Plan 2013, Chap. 15). The Marlborough District Council has designated a specific area (i.e., Coastal Marine Zone 2; CMZ2) for aquaculture use.

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[19] https://www.mpi.govt.nz/dmsdocument/18410-proposed-national-standard-for-marine-aquaculture-summary
[20] At the time of the assessment, both Marlborough Sounds and Southland were currently undertaking a review of their policies governing aquaculture and coastal management more broadly. Evaluation of these plans was outside the scope of this assessment (MSRC 2019) (Strategic Direction Southland 2019).

Although specific locations within a regional council's jurisdiction have been designated for aquaculture, expansion may be considered outside these areas if changes are made to the relevant regional coastal plan to provide for the expansion; the resource consent can then be issued. Plan changes are typically more costly and require greater public scrutiny, given that they are proposing changes to a regional-level strategic planning instrument. A plan-change mechanism was used for the NZKS expansion of three new consents in the Marlborough Sounds in 2012. Initially, NZKS had applied for nine new locations; however, only three out of the nine consents were granted. Four sites were approved by the EPA Board of Inquiry and three were subsequently confirmed by the Supreme Court. As discussed in the Effluent Criterion, NZKS currently has a proposal to relocate six farms from low flow to high flow sites, some of which are outside of the CMZ2 area (Relocation Advisory Panel Report 2017).[21] However, only three suitable sites have so far been identified by an Advisory Panel. In Southland, provisions allow for last-resort establishment of salmon refuge areas if required to maintain stock health or if environmental factors render the area unsuitable for continued production (Southland Regional Coastal Plan 2013). Other than this provision, no aquaculture can occur outside the agreed zone. On top of area-based zoning, regional councils undertake annual region level monitoring to track impact on the environment from aquaculture and other user groups (called "State of the Environment" reporting), covered in the Effluent Criterion.

Overall, the regulations and other management systems in place in NZ, particularly the establishment of zoning, (such as Aquaculture Management Areas) and mandatory monitoring for cumulative impacts, indicate an area based, cumulative management system is in place for aquaculture farms in the Marlborough Sounds and Southland; however, although following a comprehensive process, sites have been permitted outside of the area zoned as suitable for aquaculture; thus, criterion 3.2a for marine farms is scored as 4 out of 5.

Freshwater Farms

All freshwater farming occurs in the Canterbury region of NZ, more specifically, the Upper Waitaki. The Land and Water Regional Plan includes the "objectives, policies and rules as required under section 67(1) of the RMA" to manage land, water and biodiversity within the region (Canterbury Land and Water Regional Plan, Section 2, 2019). Given that the freshwater farms are located in hydrocanals where there is limited concern of any direct habitat impact as a result of the salmon farms, the greater concern relates to effluent parameters that are regulated through a nutrient discharge cap, discussed in Criterion 2. Since the nutrient discharge cap applies to aquaculture and other main user groups (i.e., agriculture), it is determined that a cumulative, area-based approach that is integrated with other industries is taken to manage the impacts of aquaculture on the ecosystem of freshwater farms. These comprehensive measures mean Criterion 3.2a has been scored 5 out of 5 for freshwater farms.

[21] Permission to relocate farms is being sought by NZKS directly with the central government (i.e., Ministry of Primary Industries, under authority of sections 360A-C of the RMA) instead of through the typical avenue of a plan change application through the regional council (Relocation Advisory Panel Report, 2017). Extensive public consultation (i.e., 596 written comments, including 408 supporting and 158 opposing) accompanied by an AEE occurred (MWH 2017).

Factor 3.2b: Enforcement of habitat management measures

Regional councils are responsible for enforcing compliance of resource consent conditions from aquaculture operations; they accomplish this through the annual monitoring reports produced by third party organizations. Highly effective enforcement is judged against the accessibility of the relevant agencies, allocation of resources to scale of industry, transparency of enforcement actions, and evidence of enforcement actions. In 2018, NZ was ranked with the second lowest perceived level of corruption, behind Denmark, by Transparency International.[22]

All three councils are readily accessible, contactable and publish information on consent conditions and the farm locations on their websites. ECAN and Environment Southland publish annual overviews of the number of consent violations and degree of action taken, ranging from advice and education to prosecution (ECAN Compliance Monitoring 2017–2018) (Environment Southland Regional Report 2018). Though monitoring reports are not publicly available for MCAS, ECAN does publish a summary of enforcement actions taken against resource consent holders throughout the region; however, this information is in summary form, and does not include the specific entities charged. Environment Southland provides an annual report covering compliance incidences, comprising the companies/persons prosecuted, charge, outcome, and the fine if assessed (Environment Southland 2018). Compliance and required actions for NZKS are publicly available on Marlborough District Council's website.

There is a high degree of transparency in the permitting/licensing of salmon resource consents, evidenced by extensive public consultation, publication of the AEE, alongside the opportunity for legal challenges to farm approvals (e.g., Supreme Court ruling on NZKS farm expansion). Given the high level of transparency around enforcement and resource consent violations overall, though recognizing that not all compliance is publicly available, the score for Factor 3.2b is 4 out of 5 for freshwater farms. For marine farms, regional councils are identifiable and contactable, and their resources are appropriate to the scale of the industry. Enforcement is active at the area-based or habitat scale, the permitting or licensing process is transparent, and evidence of penalties for infringements are available through disaggregated reports or publicly available monitoring reports detailing any non-compliances and actions taken; thus, the enforcement is considered to be highly effective and the score for Factor 3.2b for marine farms is 5 out of 5.

For freshwater farms (with the Factor 3.2a score of 5 out of 5 and a 3.2b score of 4 out of 5), the final Factor 3.2 score is 8 out of 10. For marine farms (with a Factor 3.2a score of 4 out of 5 and a 3.2b score of 5 out of 5) the final Factor 3.2 score is 8 out of 10.

Conclusions – Habitat Final Score: Marine and freshwater farms

There are robust regulations guiding the location and benthic impact requirements for marine farms. In general, information on enforcement, farm locations, and consent requirements are easily accessible from regional councils. This, combined with the relatively small size of the industry, has resulted in minimal long-term impact to the habitat. For freshwater farms, the fact

[22] https://www.transparency.org

that cultivation occurs in man-made habitats with no further significant impacts negates any concerns regarding the habitat impacts of any one farm. For marine farms, though moderate impacts occur to benthic habitats in the immediate farm area, the relative speed of recovery removes concern of long-term major environmental impacts. Factors 3.1 and 3.2 combine to give a final Criterion 3 – Habitat score of 9.33 out of 10 for freshwater farms, and 7.0 out of 10 for marine farms.

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

Marine Farms

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

Freshwater Farms

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

Brief Summary

Despite occasional high mortality events associated with disease (generally related to warm water events), reports and personal communications with veterinarians show antibiotics have not been used on any NZ salmon farms. Chinook salmon have a low vulnerability to external parasites, and similar information sources show pesticides have also not been used. All salmon farms have biosecurity plans in place, and in 2019, biosecurity best-management practices have been formally implemented. Anti-fouling paint was used historically in marine farms (never in freshwater farms), but this practice has been discontinued and replaced by mechanical net cleaning. Other chemicals such as anesthetics and disinfectants are used but are of low direct concern. As such, the final score for Criterion 4 – Chemical use for freshwater and marine farms is 10 out of 10.

Justification of Rating

Chemical treatments of concern relevant to this criterion are broadly defined as those products used in aquaculture to kill or control aquatic organisms, and/or whose use may impact non-target organisms or raise concerns relevant to human health. Chemicals such as antifoulants, anesthetics and others can be accounted for in this assessment when there is evidence of impacts. The main applications of chemicals in aquaculture operations are for controlling disease and parasites, as well as biofouling.

Despite some high salmon mortality events (most likely caused by warm-water temperatures resulting in outbreaks of two pathogens on marine farms in NZ, discussed in detail in Criterion 7 – Disease), there remains no reported use of antibiotics in marine salmon farms (NZ Aquaculture, 2014) (NZKS 2016) (Fischer and Appleby 2017) (C. Lopez, pers. comm. 2019).[23] This was confirmed by veterinarians from the marine and freshwater farms in NZ (C. Lopez, pers. comm. 2019) (G. Knowles, pers. comm. 2019). In the case of disease outbreak requiring chemical controls, chemicals would be applied via food or direct injection. Antibiotic use is regulated under the Agricultural Compounds and Veterinary Medicines Act 1997, and the Hazardous Substances and New Organisms (HSNO) Act 1996 (James et al. 2018a). Antibiotics must be prescribed by a veterinarian, and the government must be notified if added to food (MPI 2017). Both freshwater and NZKS marine farms provide biosecurity plans that cover veterinarian reporting responsibilities should antibiotics be used. NZKS is developing vaccines against diseases of concern (i.e., NZ-RLO and *T. maritimum*) rather than relying on antibiotics or chemicals (pers. comm., Lopez, 2019). Marine and freshwater farms assessed here are Best Aquaculture Practices (BAP) certified and antibiotic use (or the absence of) is verified annually through a third-party audit.

A list of chemicals kept at the largest marine farm in NZ was provided by the company's veterinarian for the purposes of this assessment (_. Lopez, pers. comm. 2019); they included: Aqui-S (fish anesthetic); Virkon-S, (footpath disinfectant); 10% buffered formalin (for sampling); quaternary ammonium compound (disinfectant); and ClearProtect24 and 30 (also disinfectants). The NZKS biosecurity plan specifies that farms use foot baths and chemicals to sanitize equipment (NZKS 2018). The Fish Health Plan in place at the freshwater farm for MCAS lists the veterinarian-controlled substances held at farms as: 10% buffered formalin (for sampling) and methyl testosterone (sex reversal of broodstock) (MCAS 2018). These chemicals are not believed to have any significant negative environmental impacts in the quantities and manners used.

Historically, anti-fouling paints were used to control bio-fouling on farm equipment (NZKS 2016). Though effective at reducing bio-fouling, these paints contained copper; paint would chip off during routine cleaning nets, and paint fragments would be released into the environment. In recognition of these concerns, and high recorded concentrations of copper in benthos (discussed in Criterion 3), NZKS stopped using anti-fouling paint in their farms in 2011; Sanford farms have also discontinued this practice (NZKS 2016) (James et al, 2018a). Instead, the industry now uses monthly in situ cleaning methods or air exposure for fish pens (NZKS 2016). As discussed in Criterion 3 – Habitat, copper continues to be detected at marine sites, but the source is increasingly unlikely to be from the farms since its use was stopped. Freshwater farms have never used anti-fouling paint (B. Blanchard, pers. comm. 2019).

[23] As a member of the Global Salmon Initiative, NZKS is required to report any antibiotic use and for the years available (2013-2017) no antibiotic use was reported (GSI 2017).

Pesticides are most-commonly used in salmon farming to treat parasitic sea lice (particularly in Atlantic salmon) with a lesser use (of hydrogen peroxide) to treat amoebic gill disease (AGD) (Aaen et al. 2015). As discussed in Criterion 7 – Disease, Chinook salmon have a low vulnerability to sea lice parasites, and pesticides have not been used in salmon farms in NZ (C. Lopez, pers. comm. 2019) (G. Knowles, pers. comm. 2019).

Conclusions and Final Score – Marine and freshwater farms

There have been no incidents of antibiotic or pesticide use in NZ in either freshwater or marine salmon farms, and anti-fouling chemicals are no longer used. Although there are no specific regulations in place that would limit the frequency or total use of antibiotics or pesticides should a serious disease or parasite outbreak occur, the extended record of zero use results in a final score for Criterion 4 – Chemical Use of 10 out of 10.

Criterion 5: Feed

Impact, unit of sustainability and principle

- Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.
- Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.
- Principle: sourcing sustainable feed ingredients and converting them efficiently with net edible nutrition gains.

Criterion 5 Summary

Marine Farms

Feed parameters	Value	Score
F5.1a Forage Fish Efficiency Ratio (FFER)	1.82	5.45
F5.1b Source fishery sustainability score	-5.00	
F5.1: Wild fish use score		3.62
F5.2a Protein IN (kg/100kg fish harvested)	28.24	
F5.2b Protein OUT (kg/100kg fish harvested)	22.94	
F5.2: Net Protein Gain or Loss (%)	-18.78	8
F5.3: Feed Footprint (hectares)	14.06	5
C5 Feed Final Score (0-10)		**5.06**
Critical?	NO	**YELLOW**

Freshwater Farms

Feed parameters	Value	Score
F5.1a Forage Fish Efficiency Ratio (FFER)	1.58	6.06
F5.1b Source fishery sustainability score	-5.00	
F5.1: Wild fish use score		4.48
F5.2a Protein IN (kg/100kg fish harvested)	45.66	
F5.2b Protein OUT (kg/100kg fish harvested)	26.07	
F5.2: Net Protein Gain or Loss (%)	-42.91	5
F5.3: Feed Footprint (hectares)	14.75	5
C5 Feed Final Score (0-10)		**4.74**
Critical?	NO	**YELLOW**

Brief Summary

Feed composition data were provided by the major feed companies for each of the three main Chinook farms in NZ. All three farms (NZKS, Sanford, and MCAS) also supplied their specific production values (e.g., eFCR). For marine farms, the average eFCR was 2.0 and the calculated Forage Fish Efficiency Ratio (FFER) was 1.82 for fish oil, meaning that 1.82 tons of wild fish must be caught to provide the oil required to produce 1 ton (t) of farmed Chinook salmon. The wild fish used in feed are sourced across numerous fisheries worldwide (Peruvian anchovy and Indian oil sardine are the primary species) with an overall sustainability score of –5 out of –10. The Wild Fish Use score for marine farms is 3.62 of 10. There is a minor net edible protein loss of 19%, and a feed footprint (land + ocean area needed to produce one ton of Chinook salmon) of 14.75 hectares (ha). The final combined score for Criterion 5 – Feed for marine farms is 5.06 out of 10.

For freshwater farms, the eFCR was 1.65 and the FFER 1.58 for fishmeal, and the fisheries sourced were similar to that of the marine feed, resulting in a Wild Fish Use score of 4.48 out of 10. Freshwater farms have a net protein loss of 42%, and the feed footprint is 14.08 ha. The final Criterion 5 – Feed score for freshwater farms is 4.74 out of 10.

Justification of Rating

The Seafood Watch Aquaculture Standard assesses three feed-related factors: wild fish use (including the sustainability of the source), net protein gain or loss, and the feed “footprint” or global area required to supply the ingredients. For full detail of the calculations, see the Seafood Watch Aquaculture Standard document.

Marine farms

Information on feed composition for marine farms was provided by the primary feed provider, Skretting Australia, for NZKS and Sanford. Over 85% of salmon feed in NZ is supplied by Skretting Australia (NZKS 2016). Farm specific information on the economic feed conversion ratio (eFCR), protein content, and byproduct utilization was provided by each marine farming company.

Factor 5.1 – Wild fish use

<u>Factor 5.1a – Feed Fish Efficiency Ratio (FFER)</u>

Despite having a common supplier, feed formulations were substantially different between the two marine farming companies. The company specific feed composition values are presented below (Table 1), however, scoring across all Factors for Criterion 5 was conducted using the average of the values provided by each company. According to the feed supplier information, NZKS’ feed contains a higher proportion of marine ingredients than Sanford’s (Table 3). The average fishmeal and fish oil inclusion levels were 17.3% and 7.5% of feed, with 49% the fishmeal from byproduct/trimmings and just 3.5% of fish oil from byproduct sources. NZKS provided the annual eFCR value for each of their farm sites, and Sanford provided a single average eFCR value; based on these values from both companies, an industry average eFCR of 2.0 was used in this assessment.

Table 3: FFER calculations for marine farms, based on feed company data provided by Skretting Australia. Although both farms provided their own eFCR value, because of confidentiality concerns, only the average eFCR is presented here.

Parameter	Data		
	NZKS	Sanford	Average
Fishmeal inclusion level (%)	24.7	9.8	17.3
Fishmeal from by-products (%)	49.0	49.0	49.0
Fishmeal yield (from wild fish) (%)	22.5[24]	22.5	22.5
Fish oil inclusion level (%)	8.9	6.2	7.5
Fish oil from by-products (%)	7.0	0.0	3.5
Fish oil yield (%)	8.0[25]	8.0	8.0
Economic Feed Conversion Ratio (eFCR)			2.0
Calculated Values			
Feed Fish Efficiency Ratio (FFER) (fishmeal)	1.12	0.44	0.78
Feed Fish Efficiency Ratio (FFER) (fish oil)	2.07[26]	1.55	1.82
Seafood Watch FFER Score (0-10)	4.83	6.13	5.45

Calculations based on the data provided resulted in some variability across the companies, but the average FFER value is 0.78 for fishmeal and 1.82 for fish oil. The higher FFER value for fish oil is used to generate a Factor 5.1a score of 5.45 out of 10 for marine farms.

Factor 5.1 b – Sustainability of the source of wild fish

The FFER score (Factor 5.1a) is adjusted by a sustainability factor determined by the fisheries that provide marine ingredients. The default adjustment value of zero assumes that aquaculture should use sustainable feed ingredients, and an increasingly large negative penalty is generated by increasingly unsustainable sources.

Data from Skretting Australia show the majority of wild fishmeal and oil (i.e., from targeted forage fisheries) used in feed for marine farms in NZ comes from the Peruvian anchovy (*Engraulis ringens*) (84.3% of fish oil and 58.8% of fishmeal and from forage fisheries) and the Indian oil sardine (*Sardinella longiceps*) (30.2% of fishmeal and 5.6% of fishmeal from forage fisheries). The main species used in byproduct fishmeal are tuna; a mixture of species are used in byproduct fish oil, but Seafood Watch does not include these ingredients in the scoring of factor 5.1b (it is included in the analysis for feed footprint of Factor 5.3).

[24] 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).

[25] Because Peruvian anchovy is the main species used in fish oil, a species-specific fish oil yield of 8% reported in Torres (1967) was used.

[26] This FFER value for NZKS is lower than the 3.46 FFDR value reported for the same company by GSI (https://globalsalmoninitiative.org). The difference is primarily due to the fish oil yield value of 5% assumed to be used in the GSI calculations (following the ASC Salmon Standard calculations) compared to the 8% used here. Minor variations in the eFCR value used also affect these calculations.

According to Fishsource,[27] Peruvian anchovy is scored as a six or greater for the current and future health of the stock, six for management strategy, eight for management compliance, and ten for fisher's compliance. In 2017, the Peruvian anchovy fishery initiated a Fisheries Improvement Project (FIP), however, no Marine Stewardship Council (MSC) full assessment has been conducted from which to assess the fishery's sustainability against the Seafood Watch Standard (IFFO March 10, 2017).[28] Based on the Fishsource scores, this fishery scores a –4 out of –10 for Factor 5.1b. Fishsource scored the Indian oil sardine[29] as six or greater for the current health of the stock, less than six for management strategy, six for management compliance, and below six for fishers' compliance. There was no score on the future health of fish. Based on these Fishsource scores, the Indian sardine oil fishery scores –8 out of –10 for Factor 5.1b.

To calculate a single Factor 5.1b wild fish sustainability score for marine ingredients, the sustainability of each species was evaluated based on the Fishsource rating of the wild fishery. The contribution of each individual species to the total fish oil/fishmeal use was then multiplied by the respective Seafood Watch sustainability score to give an approximate weighted average. The final score for Factor 5.1b – Sustainability of the source of wild fish was –5 out of 10.

When combined, the Factor 5.1a and Factor 5.1b scores result in a final Factor 5.1 score of 3.62 out of 10 for marine farms.

Factor 5.2. Net protein gain or loss

The individual ingredient list was provided by the feed supplier for both marine farming companies, and an average of the two total protein contents (41.5% and 38.2%) of 40% was used. On average across the two feeds, the overall composition is 25% marine ingredients, 34% crop ingredients, and 41% land animal ingredients. The specific contribution of different ingredient types to the total protein was evaluated using protein content values from SFW and from literature (National Research Council 1994). Based on the average across the two feeds, the large inclusion of land-animal byproduct resulted in 65% of the total protein within the feed being supplied by ingredients that are not suitable for human consumption (e.g., land animal byproducts). Considering the average eFCR of 2.0, the edible protein input is 282.4 kg per MT of farmed salmon production.

Regarding protein outputs in the form of harvested Chinook salmon, no specific protein content of whole salmon was provided, and thus a value of 18.5% was used (Boyd et al. 2007). Between the two farms, an average of 67% of the Chinook is utilized for direct human consumption, and there is 100% utilization of the remaining non-edible byproduct. Considering the eFCR of 2.0, the edible protein input is 229 kg per ton of Chinook salmon produced.

[27] www.fishsource.org

[28] https://www.iffo.net/press-release/iffo-welcomes-peruvian-anchovy-fishery-launch-fip

[29] Fishsource has separate ratings for Indian oil sardine across different Indian states; however, Kerala is the only state where information was deemed sufficient to calculate/judge the fishery against the Fishsource sustainability parameters. Thus, Fishsource scores from Kerala were used to calculate the sustainability value for this assessment.

Table 4: The parameters used and their calculated values to determine the protein gain or loss in the production of farmed Chinook salmon. Data were provided by the two main marine farm companies, Sanford and NZKS. Though both farms provided their own eFCR value and edible yield ratio, because of confidentiality concerns, only the average eFCR and edible yield ratio is presented here.

	Feed company data		
Parameter	**NZKS**	**Sanford**	**Average**
Protein content of feed (%)	41.5	38.2	39.9
Percentage of protein from edible sources (whole fish FM, edible crops) (%)	39.7	29.8	35.4
Percentage of total protein from non-edible sources (byproducts, etc.) (%)	60.3	70.2	64.6
Feed Conversion Ratio			2.0
Edible protein INPUT per ton of farmed salmon (kg)	329.0	227.3	282.4
Protein content of whole harvested salmon (%)	18.5	18.5	18.5
Edible yield of harvested salmon (%)			67
Percentage of farmed salmon byproducts utilized (%)	100	100	100
Utilized **protein OUTPUT** per ton of farmed salmon (kg)	233	224.3	229.4
Net protein loss (%)	-29.3	-1.3	-18.8
Seafood Watch Score (0-10)	7	9	8

After the adjustment for the conversion of crop proteins to farmed fish proteins, the calculated protein output is 229.4 kg per ton of farmed salmon production with an average net edible protein loss across the two companies of 18.9%. This results in a score of 8 out of 10 for marine farms for Factor 5.2 – Net protein gain or loss.

Factor 5.3. Feed footprint

The detailed data provided by Skretting Australia (Table 5) shows the overall average feed composition across the two companies is 25% marine ingredients, 34% crop ingredients and 41% land animal ingredients. Using reference values in the SFW Aquaculture Standard, the area necessary for production of marine ingredients required for one ton of Chinook salmon from marine farms is 12.90 ha. The area necessary for production of crop and land-animal byproduct ingredients is 1.16 ha/t. The combination of these two values results in an overall feed footprint of 14.06 ha/t of farmed fish. This results in a final Factor 5.3 score of 5 out of 10.

Table 5: The parameters used and their calculated values to determine the ocean and land area appropriated in the production of Chinook salmon in NZ across the two largest marine producers, NZKS and Sanford.

Parameter	Feed company data		
	NZKS	Sanford	Average
Marine ingredients inclusion (%)	33.7	16.0	24.8
Crop ingredients inclusion (%)	32.3	35.0	33.7
Land animal ingredients inclusion (%)	33.9	48.9	41.5
Ocean area (hectares) used per ton of farmed salmon	17.53	8.32	12.90
Land area (hectares) used per ton of farmed salmon	0.98	1.33	1.16
Total area (hectares)	18.51	9.65	14.06
Seafood Watch Score (0-10)	**3**	**6**	**5***

* Note: due to the categorical scoring in 10% protein loss divisions, the final score of 5 out of 10 is not the exact average of the two company scores (3 and 6). The final score reflects the average footprint area.

Conclusions and Final Score – Marine farms

The results from data provided by Skretting Australia for NZKS and Sanford salmon feed were an FFER value of 1.82 (for fish oil), a protein loss of 18.9%, and the appropriation of 14.1 ha of primary productivity area for each ton of salmon production. The final score is a combination of the scores for Factors 5.1 (5.45 out of 10), 5.2 (8 out of 10), and 5.3 (5 out of 10) with a double weighting for the Factor 5.1 (Wild fish use). The final score for Criterion 5 – Feed for marine farms is therefore 5.06 out of 10.

Freshwater Farms

Factor 5.1. Wild fish use

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

Information on feed composition was provided by the primary feed provider for the largest freshwater farm, MCAS. Information related to the economic FCR (eFCR), protein content analysis, and byproduct utilization was provided by the farm.

According to the feed supplier, the fishmeal and fish oil inclusion were 28% and 4.8% of feed, respectively, with approximately one quarter of fish oil and fishmeal coming from byproduct sources. An eFCR value of 1.65 was provided by the farm. In recent years, MCAS has increased their farm monitoring operations, with employees recording daily measurements of fish loss/feed use, which has resulted in an improved accounting system, leading to better eFCR tracking. The eFCR is reflective of the average eFCR over the 2018/early 2019 period for all farm sites. The combination of the marine ingredient inclusion levels and eFCR result in a FFER value of 1.58 for fishmeal and 1.15 for fish oil. The score for Factor 5.1a – Feed Fish Efficiency Ratio is 6.06 out of 10.

Table 6: FFER calculations for freshwater farms, based on feed company data provided by MCAS.

Parameter	Data
Fishmeal inclusion level (%)	28.0
Fishmeal from by-products (%)	23.2
Fishmeal yield (from wild fish) (%)	22.5[30]
Fish oil inclusion level (%)	4.8
Fish oil from by-products (%)	27.1
Fish oil yield (%)	5.0[31]
Economic Feed Conversion Ratio (eFCR)	1.65
Calculated Values	
Feed Fish Efficiency Ratio (FFER) (fishmeal)	1.58
Feed Fish Efficiency Ratio (FFER) (fish oil)	1.15
Seafood Watch FFER Score (0-10)	6.06

Factor 5.1b – Sustainability of the source of wild fish

As with the marine farms, the FFER score is adjusted by a factor determined by the sustainability of the fisheries providing marine ingredients for the feed, with a default adjustment value of 0. The feed supplier provided species-level inclusion information for fishmeal, though for fish oil, no species-specific inclusion levels were provided. Thus, an equal contribution to total fish oil use was assumed across the three species (Araucanian herring (*Clupea bentincki*), Pacific chub mackerel (*Scomber japonicus*), and Peruvian anchovy).

Similar to marine feed, the primary species used for fishmeal were Peruvian anchovy (*E. ringens*) (42%) and Indian oil sardine (*S. longiceps*) (28%). Based on Fishsource scores (see marine farm Factor 5.1b section for detailed information), the Peruvian anchovy received a score of –4 out of –10 for Factor 5.1b and the Indian oil sardine a –8 out of –10 for Factor 5.1b.

A single sustainability value for marine feed ingredients was calculated using the method described above in the marine farm Factor 5.1b section. Freshwater farms received a score of was a –5 out of 10 for Sustainability of the Source of Wild Fish – Factor 5.1b. This equates to an adjustment of –1.58 to the Factor 5.1a score of 6.06. Thus, the final Wild Fish Use score (Factor 5.1) is 4.48 out of 10.

Factor 5.2. Net protein gain or loss

Protein is supplied by fishmeal, terrestrial crop sources, and land animal by-products according to the feed company data provided. The protein content of feed used in freshwater farms is 41.17%, with 44% from marine ingredients (10% byproduct), 32% crop ingredients, and 22% land animal ingredients. Feed data show that 33% of the protein comes from sources not suitable for

[30] 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).

[31] 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). Since the feed manufacturer did not provided species specific inclusion levels for fish oil, the value of 5% was used instead of a tailored species-specific value, as was used in the marine feed calculations.

human consumption; therefore, considering an eFCR of 1.65, the calculated edible protein input is 456.6 kg per MT of farmed salmon production.

MCAS reports a 62% edible yield of harvested Chinook, with 100% utilization of any byproduct, and they send harvested salmon for third party protein content lab analysis; thus, the freshwater industry specific protein content value of 20% was used instead of the reported 18.5% protein content for salmon (Boyd et al. 2007). Freshwater reared salmon have a higher protein content, and therefore a higher protein ratio than marine reared Chinook salmon because fast-moving water from the hydroelectric canals leads to greater muscle development than generated in moderate current marine regions.

Table 7: The parameters used and their calculated values to determine the protein gain or loss in the production of Chinook salmon on freshwater farms.

Parameter	Feed company data
Protein content of feed (%)	41.17
Percentage of protein from edible sources (whole fish FM, edible crops) (%)	67.22
Percentage of total protein from non-edible sources (byproducts, etc.) (%)	32.78
Feed Conversion Ratio	1.65
Edible protein INPUT per ton of farmed salmon (kg)	456.6
Protein content of whole harvested salmon (%)	20
Edible yield of harvested salmon (%)	62
Percentage of farmed salmon byproducts utilized (%)	100
Utilized **protein OUTPUT** per ton of farmed salmon (kg)	260.7
Net protein loss (%)	42.9
Seafood Watch Score (0-10)	**5**

After the adjustment for the conversion of crop ingredients to farmed fish, the calculated protein output is 260.7 kg/t of farmed salmon production and a net edible protein loss of 42.9%. This results in a score of 5 out of 10 for freshwater farms for Factor 5.2 – Net protein gain or loss.

Factor 5.3. Feed footprint

The calculated area necessary for production of marine ingredients required for one ton of Chinook salmon from freshwater farms is 14.08 ha/t of farmed fish. The area necessary for production of crop and land-animal byproduct ingredients is 0.67 ha/t. The combination of these two values results in an overall feed footprint of 14.75 ha/t of farmed fish. This results in a final Factor 5.3 score of 5 out of 10 for freshwater farms.

Table 8: The parameters used and their calculated values to determine the ocean and land area appropriated in the production of freshwater farmed Chinook salmon.

Parameter	Feed company data
Marine ingredients inclusion (%)	32.8
Crop ingredients inclusion (%)	41.7
Land animal ingredients inclusion (%)	23.0
Ocean area (hectares) used per ton of farmed salmon	14.08
Land area (hectares) used per ton of farmed salmon	0.67
Total area (hectares)	14.75
Seafood Watch Score (0-10)	**5**

Conclusions and Final Score – Freshwater farms

The results from data provided by the sole feed supplier of the largest Chinook freshwater farm in NZ were an FFER value of 1.58 (for fishmeal), a protein loss of 43%, and the appropriation of 14.75 ha of primary productivity area for each ton of salmon produced. The final score is a combination of the scores for Factors 5.1 (4.48 out of 10), 5.2 (5 out of 10), and 5.3 (5 out of 10) with a double weighting for the Factor 5.1 (Wild Fish Use). The final score for Criterion 5 – Feed for marine farms is therefore 4.74 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

Marine Farms

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

Freshwater Farms

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

Brief Summary

Chinook salmon were first brought to NZ in the 1870s for the purposes of initiating a commercial fishery, and although this commercial venture failed, Chinook salmon became fully established and now form an important recreational fishery. Fish and Game NZ produce and release large numbers of Chinook smolt to support this fishery in both the freshwater and marine environment. The salmon farm net pens are vulnerable to escape, and many losses have occurred in NZ, but the established status of the species and purposeful release of Chinook by a non-profit organization (Fish and Game NZ) for recreational purposes mean that escapes are not considered to cause significant additional ecological impacts. Therefore, the final numerical score for Criterion 6 – Escapes is 10 out of 10 for both marine and freshwater farms.

Justification of Rating

This criterion assesses the risk of escape (Factor 6.1) with the potential for impacts according to the nature of the species being farmed (Factor 6.2). The potential for recaptures is a component of Factor 6.1. See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.

Factor 6.1. Escape risk for marine and freshwater farms

As long as facilities are not fully contained, the escape of farmed fish into the wild is considered inevitable, and the net pens used in salmon farming offer the greatest opportunity for escapes because there is only a net barrier between the fish and the wild (Glover et al. 2017). Chinook salmon were first brought to NZ in the 1870s for the purposes of initiating a commercial fishery (NZKS, 2016). Though not fished commercially, there is an ongoing recreational fishery for Chinook in NZ, and hatchery-raised fish continue to be deliberately released to supplement it. Fish and Game NZ produces Chinook for release in their own hatcheries, and some commercial hatcheries produce fish for farming and release purposes. MCAS and NZKS have donated or continue to donate fish for release (B. Blanchard, pers comm. 2019).

Net pens are farm structures at high risk for escape events, and these do occur in NZ. For example, although NZKS reported no escape incidences from 2013-2016, 3,500 salmon escaped in 2017 as result of a ripped net, which resulted in altering their harvesting procedures (GSI, 2017). MCAS reported 14 escape events between 2017 and to date in 2019, ranging from 50-1000 fish with most between 50 to 100 fish lost. As an indirect example, a commercial fishery trawler caught 400 salmon as bycatch in 2017, of which 372 were farm escapees and 22 were wild fish (*Otago Daily Times* 2017). No escape data were available from Sanford farms.

Chinook are released annually from hatcheries run by the non-profit organization Fish and Game NZ, with an estimated 200,000 released annually (Fish and Game NZ, pers. comm. 2019). Salmon farms and hatcheries also contribute to smolt releases for recreational fishing by releasing sometimes substantial quantities of smolt (e.g., up to 100,000 smolt were released by MCAS in 2012) (C. Johnston, pers comm. 2014). Thus, the number of salmon that may escape in a large-scale escape event are far eclipsed by the Chinook historically released for recreational stocking purposes.

Furthermore, the existence of a year-round recreational fishery in NZ in both marine areas near salmon farms and in hydrocanals also means that some percentage of farmed salmon are recaptured (MCAS 2012) (*Otago Daily Times* 2017). In the case of the commercial trawler vessel, fishing in the region was suspended for a period after the 400 salmon bycatch because of concern on the impact these takes would have on recreational fishing catches (*Otago Daily Times* 2017).

Overall, although the number of escapes from farms is dwarfed by deliberate releases, the vulnerability of the net pen production system as demonstrated by the frequently reported escape events is recognized here with an initial score of 2 out of 10 for Factor 6.1.

Factor 6.2. Competitive and genetic interactions for marine and freshwater farms
This factor considers whether the escaping species would have an adverse ecosystem impact were it to escape.

Chinook was introduced and established in NZ before salmon farming began and it continues to be deliberately stocked in large numbers. Although escapes from salmon farms occur in both marine and freshwater environments, the characteristics of the receiving environment mean that escapes in the reported numbers are not considered to cause significant additional ecological impacts (Forrest 2007) (MPI 2013). In further support of this conclusion, no evidence or comments were submitted to the Board of Inquiry for the NZKS expansion and relocation (of which 596 comments were received) concerned with potential environmental impacts as a result of escapements (MWH 2017). The score for Factor 6.2 for both marine and freshwater farms is 10 out of 10.

Conclusions and Final Score – Marine and freshwater farms
Although the farming system is vulnerable to escape, the established status of the species and the ongoing deliberate stocking by Fish and Game NZ means that there are not considered to be additional ecological impacts from escapes from marine or freshwater farms. The scores from Factors 6.1 and 6.2 combine to give a final numerical score of 10 out of 10 for Criterion 6 – Escapes for both marine and freshwater farms.

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 Evidence-based assessment

Marine Farms

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	8	
Critical?	NO	GREEN

Freshwater Farms

Pathogen and parasite parameters	Score	
C7 Disease Score (0-10)	8	
Critical?	NO	GREEN

Brief Summary

While pathogens are naturally present in the marine and freshwater environment and have caused occasional disease outbreaks on a small number of sites (two sites from 2012 to 2015), there has been no significant amplification or outbreak of diseases in the NZ salmon industry. An analysis of disease risks from marine farms in NZ identified five diseases that posed substantial threat/risk which included Rickettsia-like bacteria (NZ-RLO), aquatic birnavirus, amoebic gill disease (*Neoparamoeba perurans/Cochliopodida* sp.), and sea lice (*Caligus* spp.). NZ-RLO and *Tenacibaculum maritimum* have been found to be widespread across marine farms in NZ, but an official investigation identified that mortality events on two sites associated with the disease were most likely a result of multiple factors including unseasonably warm water temperatures and low flow, and reduced feed intake in combination with NZ-RLO. NZ-RLO has not been detected in wild fish. Although various biosecurity control and management practices are in place in both marine and freshwater farms, Chinook are considered largely resistant to parasites such as sea lice and amoebic gill disease, and academic studies provide additional information supporting the conclusion that pathogens and parasites on farms do not currently significantly infect or affect wild fish populations. Though pathogens and parasites are present in the hydro-electric canals, there have been no disease outbreaks reported on freshwater farms in NZ. With no current reported major outbreak beyond isolated NZ-RLO cases, the inherent risk of disease transfer/amplification from net pens results in a score of 8 of 10 for marine and freshwater farms.

Justification of Rating
Criterion 7 assesses the role that the cultured species may play in amplifying or transferring pathogens to wild marine species. The evidence-based scoring was used, given the high data availability (Score 7.5) due to mandatory government reporting of disease occurrences.

Biosecurity risks in aquaculture operations in NZ are regulated under the Biosecurity Act (1993) (Fischer and Appleby 2017). Under this act, aquaculture farms are required to notify MPI of the presence or possibility of any organism not usually seen in NZ waters. NZ is a member of the World Organization for Animal Health (OIE) and is required to report the existence of any animal diseases listed by OIE (OIE n.d.). Only three reports of an exceptional epidemiological event from the aquatic environment has occurred in NZ from 2005 to 2019, which were for the pathogens *Bonamia ostreae* and *Perkinsus marinus*; these impact shellfish and are not relevant to salmon aquaculture (OIE, accessed March 2019)[32].

All salmon farms in NZ conduct frequent (typically daily) inspections of fish, and monitor fish for moribund or clinical signs of disease (NZFSA and Aquaculture NZ 2019). Biosecurity is discussed in detail in Criterion 10X.

Marine Farms

NZ had limited disease outbreaks in Chinook salmon marine farms until mortality events ranging from 30 to 70% occurred for Chinook salmon at two NZKS sites in the Marlborough Sounds region from 2012 and 2015. This resulted in increases in investigations and regulations for biosecurity management (Fischer and Appleby 2017). A 25% mortality rate is common in NZKS farms but in 2012, this increased to 30% at one site where fish appeared lethargic, had a reduced feed intake, and displayed superficial skin lesions before death (Fischer and Appleby 2017). This site (and one other) continued to experience high fish mortalities through 2015 with mortality reaching 70% (Fischer and Appleby 2017). These mortality incidences were restricted to only two NZKS sites (i.e., Waihinau Bay and Forsyth Bay).

The initial reason for the 2012 mortalities were unknown, but diagnostic testing from moribund salmon from 2012 to 2015 revealed the presence of a bacterial, Rickettsia-like organism (hereafter NZ-RLO)[33] and bacterium *Tenacibaculum maritimum* (Fischer and Appleby 2017). The risks and implications of the recent disease outbreak for marine salmon farms in NZ are discussed below along with other diseases present/of concern for Chinook aquaculture.

There are 21 infectious agents and 13 non-infectious diseases reported in farmed and wild NZ Chinook salmon (Diggles 2011) (Diggles 2016), but only 5 posed a substantial enough threat to either wild or farmed fish populations to require an in-depth risk assessment. These were: NZ-

[32] www.oie.int
[33] NZ-RLO has been found to be genetically distinct from *Piscirickettsia salmonis,* which has been responsible for disease outbreaks throughout major salmon producing nations (Fischer and Appleby 2017).

RLO, aquatic birnavirus, amoebic gill disease (*Neoparamoeba perurans/Cochliopodida* sp.), sealice (*Caligus* spp.), and whirling disease (*Myxobolus cerebralis*).

All of these organisms, excluding the aquatic birnavirus, occur in cultured salmon in NZ but none are believed to cause significant risk of diseases in wild fish populations (Diggles 2016). For marine cultured salmon, NZ-RLO, aquatic birnavirus, and sea lice were determined to have potential to cause significant disease issues (Diggles 2016).

NZ-RLO – Posing the greatest risk to the NZ salmon industry, NZ-RLO is listed as an unwanted organism under the Biosecurity Act (Fischer and Appleby 2017). As described above, it was detected from moribund salmon taken from two NZKS sites from 2012 to 2015 when significant mortality occurred (i.e., 30 to 70%) (Fischer and Appleby 2017). Of the Rickettsia-like organisms, *Piscirickettsia salmonis* is the most widely studied, and responsible for disease outbreaks throughout major salmon producing nations such as Norway and Chile (Fischer and Appleby 2017). NZ-RLO is genetically distinct from *P. salmonis* (Fischer and Appleby 2017).

The causative explanation for mortalities are unknown, but a government investigation determined they were most likely caused by high-water temperatures (i.e., above 18°C) and a decline in feed intake a month prior to the mortality peak. These factors created conditions making fish susceptible to clinical disease (i.e., NZ-RLO and *T. maritimum*) as a result of the immune weakening effects of thermal and nutritional stress (Fischer and Appleby 2017). No NZ-RLO associated mortalities have occurred since 2015 (Brosnahan et al. 2019). A study published in 2019 found NZ-RLO to be present in salmon collected in the Marlborough Sounds and Canterbury, but not Big Glory Bay (Brosnahan et al. 2019). Despite the widespread presence of NZ-RLO in Marlborough Sounds, only two sites (i.e., Waihinau Bay and Forsyth Bay) had excessively high salmon mortality in the summer months (February to May) from 2012 to 2015 (Fischer and Appleby 2017).

Low flow sites in the Marlborough Sounds are most vulnerable to disease outbreak because conditions are already suboptimal for salmon cultivation, such as warmer sea temperatures and lower current flows, which heightens the susceptibility of bacterial infections if environmental conditions become unfavorable (Brosnahan et al. 2017). To further reduce risk of the spread and contraction of NZ-RLO, relocating farms from suboptimal low flow to high flow sites was recommended (Diggles 2016); NZKS has a proposal to relocate 6 of its low flow to high flow sites. NZ-RLO is unlikely to originate from freshwater hatcheries because *P. salmonis* (a similar but distinct organism) does not survive long in freshwater (Fischer and Appleby 2017). There is perceived to be low to moderate risk for the transferability of NZ-RLO to wild fish populations depending on whether farmed salmon are clinically infected or not (Diggles 2016). No detection of NZ-RLO in wild fish has occurred to date (Diggles 2016) (Fischer and Appleby 2017).

Tenacibaculum maritimum – This gram-negative bacterium has affected many marine fish species globally and is ubiquitous in the marine environment. It has been detected in all three marine farming regions in NZ (with a strain identical to that found in Tasmania) and was first found alongside NZ-RLO in the 2012 to 2015 summer mortality events (Fischer and Appleby 2017)

(Brosnahan et al. 2019). The susceptibility/subsequent mortality of salmon to *T. maritimum* increases with higher water temperatures and lower water salinities (Fischer and Appleby 2017). *T. maritimum* only occurs in marine waters and there is little is known about the reservoirs for this disease in the marine environment. It is possible that NZ-RLO and *T. maritimum* have a synergistic affect which increases mortality rates in infected salmon species—though this hypothesis remains unconfirmed (Fischer and Appleby 2017).

Aquatic birnavirus – The aquatic birnavirus has been identified in wild Chinook salmon populations and juvenile turbot (*Colistium nudipinnis*) (Diggles 2016). Aquatic birnavirus is no longer required to be reported under the OIE but MPI must be notified if it is detected within NZ (Diggles 2016). It is not believed to be pathogenic in salmon, but it may cause issues in other wild fish, as well as in salmon under certain husbandry and environmental conditions. A local strain of birnavirus exists, and most marine teleost and invertebrates in NZ are at risk of exposure (Diggles 2016). The likelihood of cultured Chinook salmon contracting and propagating the birnavirus in significant quantities is low since broodstock salmon used by NZKS are held in freshwater their entire lives, where the birnavirus does not exist. For fish species, spread of the aquatic birnavirus occurs through live fish and eggs and not by being excreted into the water column. Given this, the overall risk estimation for wild marine organisms was determined to be very low, but unknowns regarding the prevalence of birnavirus in fish populations and cultured Chinook salmon's ability to act as a conduit for this pathogen complicate a risk assessment (Diggles 2016).

Amoebic gill disease (AGD) – First detected in 1984 in salmon pens in Tasmania, the amoebic gill disease has emerged as a significant financial issue in salmon culturing, particularly for Atlantic salmon. Farmed Chinook salmon in NZ are commonly infected with amoebic gill disease but the impact has been relatively insignificant and Chinook salmon are believed to be resistant to significant outbreaks (Munday et al. 2001) (C. Kennedy, *pers comm*, in Mitchell et al. 2011). Wild fish populations exposed to the amoebic gill disease in high densities under adverse environmental conditions may be susceptible to infection. A non-negligible risk of transmission between cultured Chinook salmon and wild fish adjacent to sea cages exists (Diggles 2016).

Sea lice – While sea lice are a major threat to Atlantic salmon production, Chinook salmon are less susceptible to sea lice than Atlantic salmon (Johnson and Albright 1992); as a result, globally, Chinook salmon farms do not experience significant sea lice infections (and do not have to employ lice treatments). Several species of sea lice (*Caligus elongatus*, *Caligus epidemicus*, and *Caligus longicaudatus*) have been recorded in wild fish in NZ, including flat fish and cultured Sockeye salmon, but have not been detected on Chinook salmon (Diggles 2016). No information is available on the prevalence of sea lice in NZ. Despite never having an incident of sea lice on Chinook salmon in NZ, because sea lice can infect a range of hosts and may switch hosts if the intensity of Chinook salmon in NZ increases, the risk and establishment of sea lice was determined to be non-negligible with a moderate likelihood of exposure to wild fish populations (Diggles 2016).

Freshwater farms

No disease outbreaks have been reported on freshwater farms in NZ and there are not assumed to be a risk of transfer to wild fish populations or amplification (B. Blanchard, pers comm. 2019). Pathogens of greatest concern are whirling disease (i.e., *M. cerebralis*) and the enteric red-mouth disease (*Yersinia ruckeri*). Despite the existence of various pathogens and parasites present in the hydro-electric canals, MCAS has employed biosecurity measures that address actions to take should an endemic or exotic disease be detected (G. Knowles, pers comm. 2018). Frequent visual inspections, including diagnostic tests performed at the NZ Government Animal Health Laboratory and cover all cytopathic viruses, *Myxobolus cerebralis, Aeromonas salmonicida, Yersinia ruckeri* and *Renibacterium salmoninarum,* are also performed across all farm sites (MCAS 2018). Procedures strengthen the likelihood of early detection of any disease outbreaks. All New Zealand salmon companies are signatories to the A+ Biosecurity Standards, which require specific protocols to be implemented across all farms (MCAS 2018). Biosecurity for freshwater farms is further discussed in Criterion 10Xb.

Conclusions and Final Score – Marine and freshwater farms

Though evidence shows that certain pathogens may be common across the farms (e.g., NZ-RLO) and cause occasional outbreaks, there is no evidence that infection rates in wild fish have increased. However, because of the open nature of marine farms and the existence of pathogens in farmed species, a risk of transmission remains, but there is currently no evidence of physiological impacts to wild fish. The final numerical score for Criterion 7 – Disease is 8 out of 10.

Despite the lack of any reported disease outbreaks in freshwater canals in NZ, the open nature of net pens means exposure of diseases is possible, and thus an inherent element of risk remains. The high degree of data availability concerning disease assessment (data score of 10 out of 10) justified the use of the evidence-based evaluation. The final numerical score for freshwater farms in NZ for Criterion 7 – Disease is 8 out of 10.

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

Impact, unit of sustainability and principle

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

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

Criterion 8X Summary

Marine Farms

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

Freshwater Farms

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

Criterion 8X Summary

All farmed Chinook stock (broodstock, eggs, and juveniles) are sourced from hatcheries and domesticated populations and are therefore entirely independent of wild fisheries. The Final score for Criterion 8X – Source of Stock is therefore a deduction of zero for both marine and freshwater farms.

Justification of Ranking

Criterion 8X is a measure of the aquaculture operation's independence from active capture of wild fish for on-growing or for broodstock.

Marine and Freshwater

No importations of Chinook broodstock into NZ have occurred since 1907 (NZKS 2016). Furthermore, all farm production is dependent on hatcheries that produce their own eggs and smolt from domesticated broodstock (NZKS 2016) (B . Blanchard, pers. comm. 2019) (Sanford, n.d). In conclusion, all farmed Chinook stock is entirely independent from wild fisheries, hence, the final numerical score for Criterion 8X – Source of Stock is a deduction of 0 out of –10.

Criterion 9X: Wildlife and predator mortalities

Impact, unit of sustainability and principle

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

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

Criterion 9X Summary
Marine farms

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score (0-10)	**-4**	
Critical?	NO	**YELLOW**

Freshwater farms

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

Brief Summary
Marine salmon farms potentially impact several species of birds and marine mammals that are native to Big Glory Bay and the Marlborough Sounds. There are six potentially impacted species listed by the NZ Department of Conservation as nationally endangered (NZ king shag, black-billed gull, black-fronted tern, bottlenose dolphin, southern right whale, and Hector's dolphin). There have been ten dolphin mortalities since 1999 at NZKS sites, with one possible mortality of a Hector's dolphin in 2005 and a bottlenose dolphin entanglement and subsequent mortality in 2010. No reported dolphin mortalities have occurred at Sanford farms, which the company attributes to the absence of predator nets used to reduce seal interactions. There were 16 NZ fur seal mortalities at NZKS farm sites from 2013 to 2018; Sanford has not reported any seal mortalities. Three bird mortalities have been reported at NZKS from 2013 to 2018 and NZKS has a king shag management plan and conducts a consensus every three years to ensure interactions do not harm the nationally endangered population. The potential for undetected or unreported mortalities is noted here, but though the risk of entanglements of an endangered species is of concern, the low number of marine mammal and bird mortalities reported in marine farms throughout NZ are considered unlikely to impact the population status of the

affected species. The final numerical score for Criterion 9X – Wildlife and Predator Mortalities is a deduction of –4 out of –10 for marine farms.

Potential predator interactions in freshwater farms are limited to birds. Bird nets and other deterrents are used to reduce predation, but no entanglements or mortalities have been reported in freshwater farms. Although there is also the potential for undetected or unrecorded mortalities, there are considered to be no significant mortalities at freshwater farms, and the final numerical score for Criterion 9X – Wildlife and Predator Mortalities is a deduction of –4 out of –10 for marine farms.

Justification of Rating

The presence of farmed salmon in net pens at high density inevitably constitutes a powerful food attractant to opportunistic coastal marine mammals, seabirds, and fish that normally feed on native fish stocks (Sepulveda et al. 2015). These predators can become entangled in nets and other farm infrastructure resulting in mortality. See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.

Marine Farms

Mortalities of marine mammal and bird species caused by interactions with marine salmon aquaculture in NZ are a concern. Fifty-seven marine mammal species/sub-species occur in NZ with 14% considered threatened (Baker et al. 2016; Table 9). Within the threatened species, five are listed as "Nationally Critical," two are "Nationally Endangered" and one is "Nationally Vulnerable" (Table 9). Hector's dolphin is endemic to NZ and is on both the Nationally and IUCN "Endangered" list (Table 9). Due to geographic overlap with marine salmon farms, the NZ sea lion, Hector's dolphin, common dolphin, dusky dolphin and NZ fur seal are determined to be at high risk of entanglement (Table 9). Legally, all marine mammals are provided full protection under the Marine Mammal Protection Act 1978 with subsequent reporting requirements when mortalities or entanglements occur (Cawthron 2016).

Table 9: Marine mammals listed as threatened in NZ waters or where interactions with aquaculture are a concern. The IUCN status is included. (NZ species classification from Baker et al. 2016, Department of Conservation (DOC), and IUCN website, accessed February 9, 2019) (LC = Least Concern, DD = Data Deficient, E = Endangered, NA = Not Available)

NZ status	Common name	Interaction concern?	IUCN status	Population
Nationally Critical	Bryde's whale	No	LC	16,585 (South Pacific 1980)
	Māui dolphin	*No*	NA	57-75
	Southern elephant seal	*No*	LC	607,000 (in 1990)
	Orca whale	*Low*	DD	132 (NZ)
	NZ sea lion	*Yes*	E	12,000
Nationally Endangered	Hector's dolphin	*Yes (unconfirmed)*	E	7,456-9,130 (seasonal)

	Bottlenose dolphin	*Yes*	LC	637 (NZ)
Nationally Vulnerable	Southern right whale	Low	LC	2,169 whales in NZ waters
Not threatened	Common dolphin	*Yes*	LC	Unknown (believed significant)
	Dusky dolphin	*Yes*	DD	12,000–20,000 (NZ)
	NZ Fur seal	*Yes*	LC	200,000 (+)

Marine mammal entanglements at salmon farms

The only reported marine mammal mortalities in NZ have been from NZKS net pens in the Marlborough Sounds (Table 10). NZKS reports annual marine mammal mortalities on the GSI website.[34] Sanford farms have not reported any marine mammal mortalities. The nine dolphin mortalities from 1999 to 2019 are suspected (three mortalities were not positively identified) to include dusky dolphins (7), a Hector's dolphin (1), and a bottlenose dolphin (1) (Table 10). The exact species remain unknown in certain entanglement mortalities, particularly in the case of Hector's dolphin (Cawthron 2016). There have been no reported mortalities of any dolphin or whale species at Sanford farms, but the farm does report that bottlenose dolphins have been known to swim between nets and under cages (James et al. 2018a).

Table 10: NZ Chinook farming dolphin mortalities. No marine mammal mortalities have been associated with Sanford. Source: (Cawthron 2016) (NZKS press releases 2018).

Species	Number	Site	Year	Cause	Response
Dusky dolphin	2	Ruakaka	1999	Entrapment or entanglement	Significant changes in predator net design and operational procedures
Hector's dolphin (no formal identification)	1	NZKS Ruakaka	2005	Unknown • Either lost under pen and drowned or; • Natural causes and washed under the net	Reporting Multiple unsuccessful attempts to recover dolphin
Bottlenose dolphin	1	Crail Bay (pre-NZKS)	2010	Entanglement in net during removal	Reporting Site sold to NZKS
Dusky dolphin	1	Crail Bay	2011	Snout tangled in slack tensioned netting	NZKS in process of adapting farm to comply with policies and procedures at time of entanglements
Dusky dolphin (possibly a common dolphin. No formal identification)	1	Crail Bay	2011	Snout tangled in slack tensioned netting	NZKS in process of adapting farm to comply with policies and procedures at time of entanglements
Dusky dolphin	1	Waihinau Bay	2012	Entrapment during net decommissioning. Found under predator net	Changing to smaller net mesh size (200 mm.) (Cawthron 2014)

[34] https://globalsalmoninitiative.org/en/sustainability-report/sustainability-indicators/

Dusky dolphin	1	Forsyth Bay	2013	Found under predator net	NA
Dolphin (No formal identification)	1	Waihinau Bay	2018	Sighted in net. Mortality unconfirmed.	NA
Dusky dolphin	1	Kopaua	2018	Occurred due to entanglement with the farm predator nets	NA

Both the Hector's dolphin and the bottlenose dolphin are listed as nationally endangered; they are the species of greatest concern regarding potential aquaculture impacts. There was one unconfirmed Hector's dolphin mortality in NZKS nets (2005) and one bottlenose dolphin death (2010) (Table 10). Hector's dolphin is endangered due to a moderate population size (~8,000 mature individuals, with population varying seasonally) and declines are predicted to continue (Baker et al. 2016) (IUCN 2019). Despite a global distribution and an IUCN status of "Least Concern," the bottlenose dolphin is endangered in NZ waters because of the naturally small population of mature individuals (Baker et al. 2016). There are three distinct populations of bottlenose dolphins: Bay of Islands (483), Cook Strait/Marlborough Sounds (211), and Fiordland (205). The population in the Marlborough Sounds is semi-resident, though migration/transience is high (Cawthron 2016). Other species with reported mortalities in marine salmon aquaculture gear include the dusky dolphin and the NZ Fur seal, both species are listed as not threatened in NZ waters (Table 9).

No whale mortalities have occurred in marine salmon farms even though the humpback whale is associated with entanglements with fishing gear in NZ, e.g., cray pot buoy lines (Cawthron 2016). Two humpback mortalities and one entanglement event occurred in salmon net pens in British Columbia, which is indicative of some risk for entanglement in marine farms in NZ (SFW 2018).

Globally, sea lions and seals frequently interact with aquaculture facilities, and both Sanford and NZKS commonly report sightings of the NZ Fur seal (Kemper et al. 2003) (Cawthron 2016) (James et al. 2018 a). The NZ Fur seal is listed as "Least Concern" (IUCN) and has no national listing (Table 9). In the Marlborough Sounds-Cook strait, the NZ Fur seal population increased at rates up to 25% per year from 1970 to 1995 (Cawthron 2016). As a result, they are extremely prevalent around the Marlborough Sounds and NZKS farming areas and have been recorded at all NZKS sites (Cawthron 2016). The seals are attracted to the salmon pens as an easy food source and adults will teach juveniles to exploit the farms for food (Cawthron 2016). As described in one report produced for NZKS, seals may attempt to "break in to the grow-out pens by climbing onto the salmon cage structures or, if access is prevented, they will haul out on the closest rocky coastline to the farm" (Cawthron 2016).

Based on annual marine mammal entanglements reported to GSI (reported as the annual average number of mortalities per site), 16 seal/sea lion mortalities occurred at NZKS farm sites from 2013 to 2018 (Table 11). Fur seal interactions are frequent, with 313 seal interactions across all farm sites between 2014 and 2015, and 67 incidences from Waitata farm in 2015 alone (Cawthron 2016). These interactions resulted in only four seal mortalities throughout this period (Table 11).

Table 11: Number of seal mortalities at NZKS sites based on annual data reported to GSI. The GSI ratio is calculated by taking the total number of mortality events and dividing this by the total number of sites operating from January to December each year. Dolphin mortality numbers were taken based on those reported by NZKS in press releases/reports (GSI 2019) (Cawthron 2016) (NZKS press releases 2018). Number of sites were calculated based on annual monitoring reports that include operational history (i.e., whether the site was fallowed). [a] Forsyth site was fallowed; [b] Waihinau Bay site was fallowed (Fletcher et al. 2018).

Year	GSI Ratio	Sites	Dolphin mortality	Seal/Sea Lion mortality
2018	0.75	8	2	4
2017	0.38	8		3
2016	0.38	8		3
2015	0.16	6		1
2014	0.6	5		3[a]
2013	0.6	5	1	2[b]

NZKS has been granted a "take" permit by the NZ Department of Conservation under the Marine Mammal Protection Act. This permit enables NZKS to "catch and release seals which have entered salmon pens; harass while attempting to deter them from entering salmon pens; and injure, attract, herd, disturb and possess seals [….]. Killing of any seal (or other marine mammal) is not authorized" (Baxter 2012) (DOC 2014).

To reduce seal predator interactions in farming activities, NZKS has taken a range of approaches, which include installation of barrier netting to exclude predators, increasing net tension and strength, and establishing a seal policy training staff on specific handling procedures (Cawthron 2016). Modifying predator nets and better training are seen as the most effective approaches to reducing mortality risk for predators.

At Sanford sites, NZ Fur seals reportedly "visit the farms and push nets in to grab fish" (James et al. 2018 a). Despite these interactions, Sanford has not reported any seal mortalities at their farm sites. Currently, Sanford does not deploy predator nets, which they believe has resulted in the absence of any marine mammal entanglements (James et al. 2018 a).

Seabirds

There are three seabird species listed as nationally endangered in the Marlborough Sounds and five species from Big Glory Bay listed as nationally vulnerable or in critical condition (NZDOC 2015) (Sanford 2017 in James et al. 2018 a;

Table 12). Seabirds may be initially attracted by the pelleted feed of the farms, then become entangled in predator/farm netting and drown. In Big Glory Bay, the Southern NZ dotterel and black-billed gull are listed as nationally critical due to their small population size (i.e., the population is naturally less than 250) with large predicted declines (x>70%), respectively (Robertson et al. 2016). The king shag is the bird species of greatest interaction concern in the Marlborough Sounds, though no mortalities have been reported at NZKS sites (Schuckard 2018).

Table 12: Bird species of concern that may interact with salmon pens in the Marlborough Sounds and Steward Island (Big Glory Bay - BGB) areas (Robertson et al. 2016) (James et al. 2018 a).

Species	Threat ranking	Location
NZ king shag	Nationally endangered	Marlborough Sounds
Black-billed gull	Nationally endangered	Marlborough Sounds
Black-footed tern	Nationally endangered	Marlborough Sounds
Southern NZ dotterel	Nationally critical	Stewart Island (BGB)
Black-billed gull	Nationally critical	Stewart Island (BGB)
Fiordland crested penguin	Nationally vulnerable	Stewart Island (BGB)
Stewart Island shag	Nationally vulnerable	Stewart Island (BGB)
Yellow-eyed penguin	Nationally vulnerable	Stewart Island (BGB)
Sooty shearwater	Declining	Stewart Island (BGB)
Southern blue penguin	Declining	Stewart Island (BGB)

Because of concern over the king shag population status, NZKS was required to complete a king shag census update and prepare a king shag management plan to fulfill consent requirements for two recently granted farms (Schuckard 2018). The management plan is in place to ensure new farms do not contribute to reductions in King shags (Schuckard 2018). To measure this, NZKS must conduct a population survey every 3 years, and if a significant decline of king shag occurs from the baseline study (2015), NZKS must determine and take subsequent action if the decline is a result of farm activity. King shag population survey results in the Marlborough Sounds show a 24% decline of mature individuals from the 2015 baseline to 2018, but an increase in all areas from 2018 to 2019 such that the 2019 total was 6% less than the 2015 baseline (Table 13; Bell et al. 2019). The 2019 breeding survey counted 299 nests, the highest number ever recorded (MPI, pers comm. 2019). Reasons for the observed decline and inter-annual variability are unknown; variability may be tied to annual variations in breeding success or missing some roost sites during surveys (Bell et al. 2019). NZKS will continue to conduct annual aerial surveys of all colonies in the Marlborough Sounds in addition to placing cameras at colonies, leg banding, and GPS tracking of birds.

Table 13: Numbers of king shag recorded in each area of the Marlborough Sounds (Table from Bell et al. 2019).

Area	2015	2018	2019
Admiralty Bay	199	145	172
Pelorus	404	277	340
Port Gore	53	31	45
Queen Charlotte	103	129	160
Tasman Bay	75	51	72
Total	834	633	789

Few to no seabird deaths are reported by Sanford or NZKS or in the salmon industry overall (MPI 2013) (GSI 2017) (James et al. 2018 a); for example, one Australasian gannet was entangled in a net at a NZKS farm in 2009 (Sagar 2012), and according to NZKS self-reported information (reported to GSI), no bird mortalities occurred from 2013 to 2017 but three mortalities (species unknown) occurred in 2018 (GSI 2019). Additionally, NZKS has installed smaller mesh sizes in netting and Sanford uses anti-bird netting across the top of salmon pens to reduce the risk of bird entanglements (NZKS 2016) (James et al. 2018a). Although the reported incidents are very infrequent, it is possible that bird entanglements are not observed, recorded or reported.

Conclusions and Final Score – Marine farms

Dolphin and other marine mammals frequently interact with marine salmon farming and risk entanglement despite adoption of best industry management practices. Several species are listed as vulnerable, endangered, or critically endangered at the national or international level. Overall, the mortality numbers are limited to exceptional cases and not considered to significantly impact the affected species population size; however, given the sensitive nature of some species, the final score for Criterion 9X – Wildlife Mortalities for marine farms is a deduction of –4 out of –10.

Freshwater Farms

There are no large predator species that interact with the salmon farms in the inland freshwater hydroelectric canals, and therefore, the only species of entanglement concern are birds. No entanglements or bird mortalities have been recorded at MCAS farms, but similar to marine farms, the potential is noted here for mortalities to be undetected or unrecorded/reported.

In the hydroelectric canals in Canterbury, three types of seagulls and the black shag (distinct from the king shag) will interact with salmon net pens. The Department of Conservation considers the black shag as naturally uncommon, with a secure overseas population but restricted range within NZ (Robertson et al. 2016). This restricted range is not a result of human activity, rather, due to the populations' natural distribution pattern (Robertson et al. 2016). To deter bird predation on the smolts, MCAS deploys bird nets over all pens with fish under 500 g as well as noise deterrents (i.e., "bangers"). In the past, these bird nets only covered the top of the pens, meaning birds were capable of entering/predating on fish by entering through the sides (B. Blanchard, pers. comm. 2019). In the past few years, however, there has been a shift in net configuration where bird nets now fully cover both the top and sides of the pens (B. Blanchard, pers. comm. 2019). Although there is the potential for undetected or unrecorded mortalities, there are considered to be no significant mortalities at freshwater farms.

Conclusions and Final Score – Freshwater farms

Due to the absence of any reported predator entanglements or mortalities associated with freshwater salmon farming in NZ, and given the only predators are non-threated bird species, the final numerical score for Criterion 9X – Wildlife Mortalities for freshwater farms is a deduction of 0 out of –10.

Criterion 10X: Escape of secondary species

Impact, unit of sustainability and principle

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

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

Criterion 10X Summary

Marine Farms

Escape of secondary species parameters		Score	
F10Xa International or trans-waterbody live animal shipments		1	
F10Xb Biosecurity of source/destination		6	
C10X Escape of secondary species Final Score		**-3.6**	**YELLOW**

Freshwater Farms

Escape of secondary species parameters		Score	
F10Xa International or trans-waterbody live animal shipments		1	
F10Xb Biosecurity of source/destination		6	
C10X Escape of secondary species Final Score		**-3.6**	**YELLOW**

Brief Summary

All of NZ's aquaculture industries move stock around the country and both freshwater and marine Chinook farms are reliant on smolt produced in land-based freshwater hatcheries. A survey of NZ freshwater and marine salmon farmers showed a moderate to high concern for preventing and managing introductions of aquatic plants, other fish species, and microalgae in addition to bacterial, viral, and fungal diseases and parasites. From the same survey, approximately 70% of freshwater farmers consider it likely or very likely that pests or diseases can enter their farms through stock transfers. Although some freshwater movements occur in the same waterbody, and non-profit stockings for recreational purposes follow the same movement patterns, both freshwater and marine farms are considered largely dependent on transwaterbody movements. The tank-based hatchery systems and the biosecurity regulations and management measures offer the potential for high biosecurity, but there is little information available on how effectively these measures are enacted or enforced. Overall, the combination of a high dependence on live animal movements and moderate-good biosecurity practices result in a moderate deduction for Criterion 10X – Escape of Secondary Species of –3.6 out of –10.

Justification of Rating

This criterion provides a measure of the escape risk (introduction to the wild) of secondary species (i.e., other than the principal farmed species) unintentionally transported during animal shipments. See the Seafood Watch Aquaculture Standard for further details on all scoring tables and calculations.

Marine and Freshwater Farms

Factor 10Xa International or trans-waterbody live animal shipments

According to Sim-Smith et al. (2016), all of NZ's aquaculture sectors move stock around the country. For Chinook, fry are produced in freshwater hatcheries within NZ, and smolts are subsequently transferred to the marine or freshwater net pen growout sites. Freshwater hatcheries are often located in different areas than the farms though not further than 300 km distance (Figure 11).

NZKS' marine salmon farms are stocked from smolt produced in hatcheries from different regional councils across the South Island with the largest hatchery located south of Christchurch (Figure 11). Sanford's two hatcheries are located in the neighboring regional council of the farms (i.e., Otago).[35] For freshwater farms, MCAS sources smolt from three hatcheries; one hatchery is located on the hydroelectric canal and the two other hatcheries are located in Christchurch (R. Ramsey, pers. comm. 2019). MCAS is a full/part owner in two of the hatcheries. An average of 19% of smolt comes from the hydroelectric canal hatchery and the remainder from Christchurch (J. Bailey, pers. comm. 2019). All freshwater hatcheries for MCAS are located in the Canterbury Region (jurisdiction of Environment Canterbury).

Additionally, Fish and Game NZ releases over 200,000 Chinook smolts for recreational purpose each year (R. Cosgrove, pers comm. 2019). Although the marine farms' annual smolt production eclipses that of recreational hatcheries (i.e., NZKS and Sanford stock 2.8 million and 900,000 smolts annually, respectively), the intentional release of smolt into the aquatic environment reduces the concern that live animal movements for salmon aquaculture represent a unique risk of introducing secondary species as a result of marine farming activity (NZKS 2016)[36] although there are many more movements for the commercial farms. MCAS also releases Chinook smolt produced by their hatcheries for recreational fishing purposes into hydroelectric canals; annual numbers are not known (100,000 smolt were released in 2012 (C . Johnston, pers comm. 2014). Any release of salmon into the freshwater environment must obtain prior approval from either the Minister of Conservation (delegated to DOC) or the Minister of Fisheries (delegated to the Manager CFSA) under section 26ZM of the Conservation Act 1987.

[35] https://www.sanford.co.nz/operations/processing/

[36] https://www.sanford.co.nz/operations/processing/

Figure 11: Location of NZKS land-based freshwater hatcheries (red circles) and marine farms in the Marlborough Sounds (blue square). Map copied from (NZKS 2018 b).

Determining if these hatchery-to-farm movements represent transwaterbody movements (i.e., movements from one waterbody to an ecologically distinct waterbody such that there is a risk of transferring a secondary species from the source to the destination) is complex and discussed below.

Freshwater Farms

The movements from hatcheries to growout pens in the same hydrocanal site are clearly not transwaterbody. For all other movements, respondents in a survey of NZ freshwater and marine salmon farmers (Sim-Smith et al. 2016), showed a high or moderate concern for preventing and managing aquatic plants, other fish species, and microalgae (particularly *Didymosphena* spp.) in addition to bacterial, viral, and fungal diseases and parasites. From the same survey, approximately 70% of freshwater farmers consider it likely or very likely that pests or diseases can enter their farms through stock transfers.

The dynamics of organisms such as *Didymosphena* spp. (a mat-forming diatom known as "rock snot" or Didymo) are complex, and expert opinion (C. Kilroy, NIWA, pers. comm. 2019) indicates it is either already present in most relevant waterways, or of low concern for establishment due to river-specific nutrient dynamics).[37] Nevertheless, the biosecurity concerns for many other species of plant, pathogen, and parasite expressed by freshwater farmers in the Sim-Smith et al. survey indicate that all movements other than those in the same hydrocanal should be considered transwaterbody. As an average of 19% of movements remain at the same MCAS

[37] Didymo is not present in the spring-fed water systems around Christchurch but is unlikely to be present because the nutrient (nitrogen and phosphorus) concentrations are too high; didymo thrives only in low nutrient environments (C. Kilroy, pers. comm. 2019).

hydrocanal site, 81% of freshwater production is considered to be dependent on transwaterbody movements and the score for Factor 10Xa is 1 out of 10 for freshwater farms.

Marine Farms

The marine salmon farmer respondents in the survey of Sim-Smith et al. (2016) share the same moderate or high concern about preventing and managing disease, but in contrast, they consider it unlikely that pests or diseases can enter their farms through stock transfers. Although the movement of smolts from freshwater hatcheries to marine sites are clearly transwaterbody, a limited number of species are likely to survive; for example, Didymo would not survive in the marine environment (Kilroy and Novis 2017). Nevertheless, the somewhat circular nature of broodstock and/or ova movements from marine sites to freshwater hatcheries and their return to marine growout sites represents the potential to transfer organisms across waterbodies. With a minor adjustment in consideration of the Fish and Game NZ stocking activities that have similar movement patterns, the marine farms are also considered to be almost completely dependent on transwaterbody movements and the score is also 1 out of 10 for Factor 10Xa.

The biosecurity measures that reduce the risk of introducing secondary species during such live animal movements are discussed in Factor 10Xb below.

Factor 10Xb Biosecurity of source/destination

General biosecurity information is presented below for both marine and freshwater farms, but since the net pen farms that represent the destination of live animal shipments are typically considered "open" systems, the scoring of this factor focuses on the hatcheries as the primary source of live animal shipments.

Biosecurity is regulated at the national, regional, and farm level in NZ. At the national level, the Biosecurity Act 1993 "provides a legislative framework to manage risks from the introduction and spread of harmful organisms (pests and diseases)." Under this act, aquaculture farms are required to notify MPI of the presence or possibility of the existence of "notifiable organisms" listed under the Biosecurity Act (MPI, 2013b). The Resource Management Act and Coastal Policy Statements direct the regional councils to develop, monitor, and enforce regional management strategies related to biosecurity (MPI 2017). All salmon transfers on or off a land-based fish farm must obtain prior approval from Fisheries New Zealand. This approval process includes a health check of the farm to ensure stock is not experiencing any unusual, increased or unexplained sickness or mortalities. Fish transfer authorization is required to move smolt or broodstock between hatcheries and farm sites (Fischer and Appleby 2017). Freshwater hatcheries are also subject to health monitoring requirements with mandatory reporting to MPI if large scale mortalities or notifiable diseases are detected (MPI 2017) (J. Bradley, pers. comm. 2019).

All major freshwater and marine producers of Chinook production in NZ have established and implemented biosecurity plans at the farm level.[38] NZKS has implemented a biosecurity plan across all farms and in their freshwater hatcheries. The biosecurity plan fulfills consent conditions specified by the Marlborough Council for the new farm sites in the Marlborough Sounds and were independently reviewed (i.e., Waitata, Kopāua, and Ngamahau) (Marlborough Sounds 2016) (NZKS 2018). The biosecurity plan specifies actions and responsibilities that must be taken across various aspects of production, including stock movements. MCAS has implemented a Biosecurity Plan that applies to all their grow-out and hatchery operations, and is consistent with best management practices promulgated by Aquaculture NZ's A+ Sustainable Management Framework and Salmon Biosecurity Standards (MCAS 2018). MCAS biosecurity measures specify detection of endemic and exotic diseases, daily monitoring of fish health, and establish protocols to reduce risk during smolt transfers to farm sites. Monthly veterinarian inspections of the farm sites and tri-annual inspections of Clearwater hatchery are conducted and the mortality, morbidity, feed conversion, feed consumption and environmental data are reviewed (MCAS 2018).

A salmon-specific biosecurity standard has been recently developed by Aquaculture NZ of which all farms evaluated in this report are signatories (NZ Salmon Farmer's Association and Aquaculture NZ 2019). The plan identifies zones across freshwater, marine, hatchery, and salmon processing plants and with requirements addressing the movement of equipment, people, stock, feed, and water across zones (NZ Salmon Farmer's Association and AQNZ 2019). The standard is self-enforced and no third-party inspections are required at this time.

As mentioned above in Factor 10Xa, a particular biosecurity concern in NZ is the spread of didymo (*Didymosphenia geminata*), an invasive freshwater alga that is present in the South Island of NZ (Sim-Smith et al. 2016). The diatom was discovered in New Zealand in 2004, where it was recognized as an invasive species (Kilroy et al. 2007). Since that time, it has spread to numerous rivers and watersheds on the South Island (CABI 2019). Research shows that fish communities are negatively impacted by didymo, with reductions up to 70% of fish biomass occurring (Jellyman and Harding 2016). Didymo would not survive in the marine environment (Kilroy and Novis 2017), but despite expert opinion that the risk of further establishment in new freshwater bodies used by freshwater farms and hatcheries is low (C. Kilroy, NIWA, pers. comm. 2019),[39] freshwater salmon farmers have employed voluntary decontamination requirements to prevent its spread (Sim-Smith et al. 2016). This includes treating all salmonid eggs from didymo-positive areas before transfer to any didymo-negative areas.

Overall, the tank-based hatchery systems and the management measures described above offer the potential for high biosecurity, but there is little information available on how effectively these

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[38] The following documents provide a recent synopsis of the state of biosecurity in New Zealand's aquaculture industry and measures that can be taken to strengthen biosecurity practices: (Sim-Smith et al. 2016) (Georgiades et al. 2016) and MPI/AQNZ Aquaculture Biosecurity Handbook.

[39] Further information can be found on the NIWA website: https://www.niwa.co.nz/freshwater-and-estuaries/freshwater-and-estuaries-update/freshwater-update-62-september-2014/didymo-in-new-zealand-ten-years-on

measures are enacted or enforced. Sim-Smith et al. (2016) conclude that for aquaculture in general in New Zealand (i.e., all farmed species), there is a large variation in biosecurity practices and the high level of industry concern regarding pests and diseases is not always reflected in biosecurity practices; nevertheless, for commercial salmon farmers, they also show that there are better practices in place, and this industry (freshwater and marine salmon farms) has “moderate” biosecurity measures. The final score for Factor 10Xb for both marine and freshwater farms reflects this and is 6 out of 10.

Conclusions and Final Score – Marine and freshwater farms

Overall, both marine and freshwater farms are largely dependent on movements of live fish, and these mostly occur across ecologically distinct waterbodies such that there is a risk of transferring a secondary species during salmon movements. However, there is a process in place that requires authorizations from Fisheries New Zealand for all stock movements on or off land-based fish farms, including hatcheries. The tank-based hatchery systems and biosecurity measures offer the potential for high biosecurity, but there is little information available on how effectively these measures are enacted or enforced. The final score for Criterion 10X combines the movement score (Factor 10Xa) with the biosecurity score (10Xb) and is a moderate deduction of –3.6 out of –10.

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Appendix 1 - Data points and all scoring calculations

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

Marine Farms

Criterion 1: Data quality and availability

Data Category	Data Quality (0-10)
Industry or production statistics	7.5
Management	10
Effluent	7.5
Habitats	7.5
Chemical use	10
Feed	10
Escapes	10
Disease	7.5
Source of stock	10
Predators and wildlife	7.5
Secondary species	7.5
Other – (e.g., GHG emissions)	n/a
Total	**95.0**

C1 Data Final Score (0-10)	**8.64**	**GREEN**

Criterion 2: Effluents

Effluent Evidence-Based Assessment

C2 Effluent Final Score (0-10)	**6**	**YELLOW**
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	4
3.2b Enforcement of habitat management measures	5
3.2 Habitat management effectiveness	**8**

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

Criterion 4: Evidence or risk of chemical use

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

Criterion 5: Feed

5.1. Wild Fish Use

Feed parameters	Score
5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	17.25
Fishmeal from by-products (%)	49
% FM	8.7975
Fish oil inclusion level (%)	7.55
Fish oil from by-products (%)	3.5
% FO	7.28575
Fishmeal yield (%)	22.5
Fish oil yield (%)	8
eFCR	2
FIFO fishmeal	0.78
FIFO fish oil	1.82
FIFO Score (0-10)	**5.45**
Critical?	NO
5.1b Sustainability of Source fisheries	
Sustainability score	-5

Calculated sustainability adjustment	-1.82
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**3.62**
Critical?	NO

5.2 Net protein Gain or Loss

Protein INPUTS	
Protein content of feed (%)	39.85
eFCR	2
Feed protein from fishmeal (%)	28.79
Feed protein from EDIBLE sources (%)	35.44
Feed protein from NON-EDIBLE sources (%)	64.56
Protein OUTPUTS	
Protein content of whole harvested fish (%)	18.5
Edible yield of harvested fish (%)	67
Use of non-edible by-products from harvested fish (%)	100
Total protein input kg/100kg fish	79.7
Edible protein IN kg/100kg fish	28.24
Utilized protein OUT kg/100kg fish	22.94
Net protein gain or loss (%)	-18.78
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 (%)	24.8
eFCR	2
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)	12.90
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	33.65
Inclusion level of land animal products (%)	41.5
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	2
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	1.16
Total area (Ocean + Land Area) (ha)	14.06
F5.3 Feed Footprint Score (0-10)	5

Final Feed Score

C5 Feed Final Score (0-10)	**5.06**	**YELLOW**
Critical?	**NO**	

Criterion 6: Escapes

6.1a System escape Risk (0-10)	2	
6.1a Adjustment for recaptures (0-10)	0	
6.1a Escape risk score (0-10)	**2**	
6.2. Competitive and genetic interactions score (0-10)	**10**	
C6 Escapes Final Score (0-10)	**10**	**GREEN**
Critical?	**NO**	

Criterion 7: Diseases

Disease evidence-based assessment (0-10)	8	
Disease risk-based assessment (0-10)		
C7 Disease Final Score (0-10)	**8**	**GREEN**
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)	**-4**	
C9X Wildlife and Predator Final Score (0-10)	**-4**	**YELLOW**
Critical?	NO	

Criterion 10X: Escape of secondary species

F10Xa live animal shipments score (0-10)	1.00	
F10Xb Biosecurity of source/destination score (0-10)	6.00	
C10X Escape of Secondary Species Final Score (0-10)	**-3.60**	**YELLOW**
Critical?	n/a	

Freshwater Farms

Criterion 1: Data quality and availability

Data Category	Data Quality (0-10)
Industry or production statistics	7.5
Management	10
Effluent	7.5
Habitats	7.5
Chemical use	10
Feed	10
Escapes	10
Disease	7.5
Source of stock	10
Predators and wildlife	7.5
Secondary species	7.5
Other – (e.g., GHG emissions)	n/a
Total	**95.0**

C1 Data Final Score (0-10)	**8.64**	**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)	10

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

3.2a Content of habitat management measure	5
3.2b Enforcement of habitat management measures	4
3.2 Habitat management effectiveness	**8**

C3 Habitat Final Score (0-10)	**9**	**GREEN**
Critical?	NO	

Criterion 4: Evidence or Risk of Chemical Use

Chemical use parameters	Score	
C4 Chemical use score (0-10)	**10**	
C4 Chemical Use Final Score (0-10)	**10**	**GREEN**
Critical?	NO	

Criterion 5: Feed

5.1. Wild fish use

Feed parameters	Score
5.1a Fish In : Fish Out (FIFO)	
Fishmeal inclusion level (%)	28
Fishmeal from by-products (%)	23.2
% FM	21.504
Fish oil inclusion level (%)	4.8
Fish oil from by-products (%)	27.1
% FO	3.4992
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	1.65
FIFO fishmeal	1.58
FIFO fish oil	1.15
FIFO Score (0-10)	**6.06**
Critical?	NO

5.1b Sustainability of source fisheries	
Sustainability score	-5
Calculated sustainability adjustment	-1.58
Critical?	NO
F5.1 Wild Fish Use Score (0-10)	**4.48**
Critical?	NO

5.2 Net protein gain or loss

Protein INPUTS	
Protein content of feed (%)	41.17
eFCR	1.65
Feed protein from fishmeal (%)	45.22
Feed protein from EDIBLE sources (%)	67.22
Feed protein from NON-EDIBLE sources (%)	32.78
Protein OUTPUTS	
Protein content of whole harvested fish (%)	20
Edible yield of harvested fish (%)	62
Use of non-edible by-products from harvested fish (%)	100
Total protein input kg/100kg fish	67.9305
Edible protein IN kg/100kg fish	45.66
Utilized protein OUT kg/100kg fish	26.07
Net protein gain or loss (%)	-42.91
Critical?	NO
F5.2 Net Protein Score (0-10)	**5**

5.3. Feed footprint

5.3a Ocean area appropriated per ton of seafood	
Inclusion level of aquatic feed ingredients (%)	32.8
eFCR	1.65
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)	14.08
5.3b Land area appropriated per ton of seafood	
Inclusion level of crop feed ingredients (%)	41.7
Inclusion level of land animal products (%)	23
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.65
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.67
Total area (ocean + land area) (ha)	14.75

F5.3 Feed footprint score (0-10)	5

Feed Final Score

C5 Feed Final Score (0-10)	**4.74**	**YELLOW**
Critical?	**NO**	

Criterion 6: Escapes

6.1a System escape risk (0-10)	10	
6.1a Adjustment for recaptures (0-10)	0	
6.1a Escape risk score (0-10)	**10**	
6.2. Competitive and genetic interactions score (0-10)	**10**	
C6 Escapes Final Score (0-10)	**10**	**GREEN**
Critical?	**NO**	

Criterion 7: Diseases

Disease evidence-based assessment (0-10)	8	
Disease risk-based assessment (0-10)		
C7 Disease Final Score (0-10)	**8**	**GREEN**
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)	**0**	
C9X Wildlife and Predator Final Score (0-10)	**0**	**GREEN**
Critical?	NO	

Criterion 10X: Escape of Secondary Species

F10Xa live animal shipments score (0-10)	1.00

F10Xb Biosecurity of source/destination score (0-10)	6.00	
C10X Escape of Secondary Species Final Score (0-10)	**-3.60**	**YELLOW**
Critical?	n/a	