Monterey Bay Aquarium

Seafood Watch®

Atlantic Salmon, Coho Salmon

Salmo salar, Oncorhynchus kisutch

Image © Monterey Bay Aquarium

Chile

Net pens

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Final Seafood Recommendation – Atlantic salmon

The final numerical score of 3.73 for Atlantic salmon is at the lower end of the yellow category, but the two red criteria and particularly the critical score for chemical use mean that the final recommendation is a red "Avoid."

Atlantic salmon

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.11	YELLOW	
C2 Effluent	2.00	RED	NO
C3 Habitat	3.93	YELLOW	NO
C4 Chemicals	CRITICAL	RED	YES
C5 Feed	4.23	YELLOW	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	-4.00	YELLOW	NO
C10X Introduced species escape	-0.40	GREEN	
Total	**29.88**		
Final score	**3.73**		

OVERALL RANKING

Final Score	3.73
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES
Final Rank	AVOID/RED

Scoring note –scores range from 0 to 10 where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Color ranks: red = 0 to 3.33, yellow = 3.34 to 6.66, green = 6.66 to 10. Criteria 9X and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects very poor performance. Two or more red criteria trigger a red final result.

Final Seafood Recommendation – coho salmon

The final numerical score of 3.61 for coho salmon is at the lower end of the yellow category, but the three red criteria (Effluent, Chemical Use and Escapes) and particularly the critical score for chemical use mean that the final recommendation is a red "Avoid."

Coho Salmon

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.11	YELLOW	
C2 Effluent	2.00	RED	NO
C3 Habitat	3.93	YELLOW	NO
C4 Chemicals	CRITICAL	RED	YES
C5 Feed	4.23	YELLOW	NO
C6 Escapes	3.00	RED	NO
C7 Disease	4.00	YELLOW	NO
C8 Source	10.00	GREEN	
9X Wildlife mortalities	-4.00	YELLOW	NO
10X Introduced species escape	-0.40	GREEN	
Total	**28.88**		
Final score	**3.61**		

OVERALL RANKING

Final Score	3.61
Initial rank	YELLOW
Red criteria	3
Interim rank	RED
Critical Criteria?	YES
Final Rank	AVOID/RED

Scoring note –scores range from 0 to 10 where 0 indicates very poor performance and 10 indicates the aquaculture operations have no significant impact. Color ranks: red = 0 to 3.33, yellow = 3.34 to 6.66, green = 6.66 to 10. Criteria 9X and 10X are exceptional criteria, where 0 indicates no impact and a deduction of -10 reflects very poor performance. Two or more red criteria trigger a red final result.

Executive Summary

Chile is currently the second largest farmed salmon producer, with a total of 638,400 metric tons (mt) in 2013. Atlantic salmon is the dominant species (490,300 mt) and Chile is the only region producing substantial amounts of coho salmon (148,100 mt). This assessment covers both Atlantic and coho salmon. Current production is predominantly in Chile's Region X (Los Lagos), Region XI (Aysen), and is expanding further south into Region XII (Magallanes).

Chile is somewhat infamous for the collapse in production due to a parasite and disease outbreak between 2008 and 2011. The outbreak (of Infectious Salmon Anemia, ISA) highlighted many key aspects of poor performance and management in the industry and resulted in many changes at the production and regulatory level. The industry has evolved rapidly as a result, and although attempting to take a snapshot of current production, this Seafood Watch assessment recognizes the dynamic nature of the current situation as the industry reorganizes, rebounds, and yet continues to expand its production and range further south into what are commonly considered to be pristine environments.

The assessment involves a number of different criteria covering impacts associated with: effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability[1].

Before the ISA outbreak, academics had noted the lack of environmental studies on the impacts of the salmon farming industry in Chile. It is clear that data availability from an industry and scientific perspective has improved considerably in recent years, and is world leading in some aspects, but reliable monitoring of the environmental impacts of (for example) escapes, disease, parasites, cumulative nutrient losses, antibiotic resistance (and in particular, relating to the industry's expansion further south) are still largely lacking. It must also be emphasized that the majority of the industry data presented are collected and self-reported by the industry itself. On balance, the improved transparency of the industry and the availability of public data through Sernapesca and Sistema Integral de Atención Ciudadana (SIAC) are to be congratulated. The final data score is a moderate 6.1 out of 10.

Chilean Patagonia is the world's largest fjord system; academics and conservation organizations consider it to be one of the most pristine ecosystems in the world, and classify it among those with the highest global conservation priority worldwide due to its threats and high degree of endemism. Despite the large amounts of effluent waste discharged directly into the environment from salmon farms in Chile, there is contradictory or inconclusive evidence of direct impacts beyond the immediate vicinity of the farm. The high production density, rapid expansion and limited study of salmon farming in Chile, in addition to uncertainties regarding

[1] The full Seafood Watch aquaculture criteria are available at: http://www.seafoodwatch.org/cr/cr_seafoodwatch/sfw_aboutsfw.aspx

the effectiveness of the regulatory system, mean that the industry in Chile is different from those in other major salmon farming regions; therefore, despite more reassuring studies from other regions with respect to effluent impacts, numerous recent articles express ongoing concerns regarding potential cumulative impacts of soluble and particulate wastes from the large and rapid expansion of the industry in Chile. Ongoing questions regarding the effectiveness of the regulatory system with regard to the industry's ongoing expansion further south into pristine habitats is also a frequently cited concern. Yet despite these concerns, the industry has rebounded rapidly since the ISA crisis and total production in Chile continues to increase rapidly with a corresponding increase in Region XI and a planned southward development into pristine habitats in Region XII. This combination of factors clearly necessitates an application of a precautionary principle, and according to the Seafood Watch criteria, there is a moderate-high concern of impacts beyond the immediate farm area and/or contributions to cumulative local or regional impacts. The final score for the Effluent Criterion is 2 out of 10.

The Habitat Criterion assesses the direct impacts within the farm area, which in the case of salmon farms is the seabed beneath the net pens and within a regulatory allowable zone of effect. The channels and fjords of southern Chile have been shown to possess a unique benthic fauna of high ecological value. The floating net pens have relatively little direct habitat impacts, but the seabed impacts under them can be severe in intensity. Benthic monitoring data shows approximately a quarter of Chilean marine sites do not meet the requirements of "aerobic" (i.e., good) conditions, but the total impacts of all farm areas are limited to a relatively small spatial extent (approximately 1,300 hectares or 0.1% of the region's coastal border). The impacts are also relatively and rapidly reversible, but the industry's southward expansion has been, and continues to be a cause for concern while uncertainty remains in the capability of the developing regulatory system. Overall, the limited total area of impact and rapid reversibility is weighed against the ecological importance of the affected habitats and the uncertain expansion into pristine areas. The final score for the Habitat Criterion with respect to the immediate farm areas is 3.9 out of 10.

Wildlife interactions with salmon farming are likely to be significant in number, but there is relatively little overlap between the salmon industry and those areas identified as the highest conservation priorities in Chile. The primary concern for predator mortalities is the southern sea lion for which lethal control is illegal; however, exceptional lethal control may be permitted and/or may be unreported (and data are not available). Occasional entanglement is also likely, but the total mortality numbers are considered unlikely to have a significant impact on the population size. The penalty score for this criterion is -4 (out of -10).

High chemical use has been a defining characteristic of the Chilean salmon farming industry since its inception. Antibiotic use in Chile is extremely high and increasing. Chile's total antibiotic use in 2013 (estimated) is more than 60 times the combined totals of the other three top global salmon producing regions of Norway, Scotland and British Columbia. The relative use in Chile in terms of grams antibiotic per tonne of salmon production is 546 times that of Norway and 634 times that of Scotland. There are no regulations limiting the frequency of use of these chemicals in Chile, and the antibiotics used include those listed by the World Health

Organization as highly- and critically-important to human health. Pesticide use in Chile is also extremely high, and approximate calculations show Chile uses a hundred times more pesticide per tonne of production than British Columbia. The overuse of pesticides has led to the development of resistance to multiple treatments. The extreme and increasing use of antibiotics and pesticides in Chile in terms of both total and relative quantities results in a critical score for the Chemical Use Criterion.

Like all salmon farming regions, Chile has made substantial reductions in the use of wild fish in salmon feeds. Nevertheless, the final “fish in: fish out” value of 2.43 means that from first principles (i.e., ignoring other uses of associated fishmeal), 2.43 mt of wild fish would need to be caught to produce one tonne of Chilean farmed salmon. This is in line with FAO global predictions of 3.0 in 2010 decreasing to 2.0 in 2015. Over 60% of the feed ingredients used now come from terrestrial sources (crops and land animal by-products), giving a relatively small feed footprint, but despite improvements in feeding efficiency, salmon farming remains a substantial net loss (-35%) of edible protein. Overall, the final feed score is 4.23 out of 10.

Atlantic and coho salmon are non-native species in Chile, but data on escapes are not readily available. The construction of net pens has improved, but known escape events in Chile and other salmon farming regions highlight the fundamental weakness of the production system and the ongoing high risk of escapes. Data on recaptures and mortality are also unavailable, but due to poor feeding success, particularly in Atlantic salmon, mortality rates of escapees are likely to be high and Atlantic salmon are not considered to be a successful colonizer in Chile. Coho salmon appear to be more successful after escape and do appear to feed on native prey; they are considered partly established with the capacity to increase their range. Atlantic salmon are considered highly unlikely to establish populations in Chile. Combining the escape risk with an invasiveness score gives final scores for Atlantic salmon of 4 out of 10, and for coho salmon of 3 out of 10.

Disease has been a defining characteristic of the expansion of salmon farming in Chile, particularly the collapse in Atlantic salmon production from 2009 to 2011 due to the ISA virus. Monthly mortality rates are typically between 0.5% and 1.5%, and dominated by the bacterial pathogen *Piscirickettsia salmonis.* Unlike other major salmon farming regions, Chile does not have important wild salmon populations, and although there is evidence of infections of wild fish by parasitic sea lice, there is no evidence of significant mortalities in wild fish in Chile. The expansion of the industry into pristine areas further south represents a cause for concern, and the final score for the Disease Criterion is a precautionary 4 out of 10.

Due to the industry-wide use of domesticated broodstocks and hatcheries, the Chilean salmon farming industry is considered to be independent of wild salmon fisheries for its supply of adult or juvenile fish. The final score for the Source of Stock Criterion is 10 out of 10.

Overall, the Chilean salmon farming industry has evolved rapidly in terms of regulations and management since the ISA crisis, yet the rebounding production has been associated with massive increases in antibiotic and pesticide use, hundreds of times higher than other salmon

farming regions, due to an ongoing inability to control pathogens and parasites. The high density of production in regions X and XI continue to be a cause for concern with regard to the environmental carrying capacity of the region, and escapes of coho salmon are also a high concern. The proposed future increases in industry size make it difficult to predict an ecologically sustainable future when significant problems with the production system remain. Overall, the final recommendation for all species of farmed salmon from Chile is a red “Avoid.”

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Species Overview

Basic biology (based on FAO Cultured Species factsheets[2])
Wild Atlantic salmon are native to North Atlantic on both the European (Portugal to Russia) and North American (Cape Cod to Labrador) sides. They also occur around North Atlantic islands (e.g., UK, Iceland, Greenland). Salmon are anadromous; birth and early life stages occur in freshwater rivers and streams after which they spend up to 4 years in deep-sea feeding grounds feeding on pelagic species such as herring, sprat and squid. At the onset of maturation, fish cease feeding and return to their rivers of origin to spawn. Most fish die following spawning, although some may return to sea as "kelts."

Wild coho and Chinook salmon populations are native to the North Pacific basin. They are found from northern Japan, across the Bering Sea to Alaska, and south to California. With a similar life history to Atlantic salmon, coho salmon usually mature during their third year of life.

All three species are non-native in Chile, although several historic attempts have been made to establish them for sport fishing.

Production statistics
Chile produced nearly half a million tonnes of Atlantic salmon in 2013 (490,300 mt) and nearly 150,000 tons of coho salmon (148,100 mt). According to SalmonChile, (a trade association that brings together the major salmon producers and providers in Chile) there have been no significant harvests of farmed king (Chinook) salmon since 2009. Figure 1 shows the production figures since 2005, and highlights the collapse in Atlantic salmon due to sea lice parasites and the ISA virus during 2008–2011. Production in 2013 has now exceeded the pre-ISA volumes.

[2] http://www.fao.org/fishery/culturedspecies/search/en

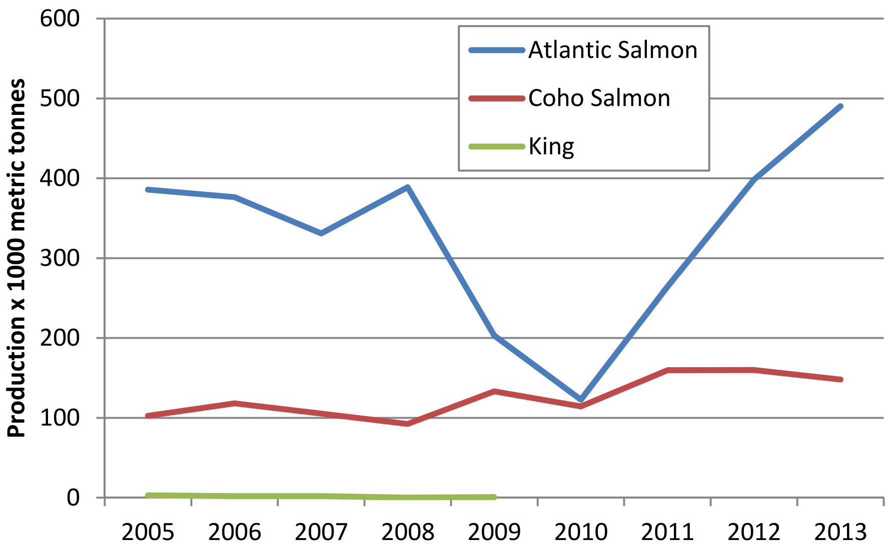

Figure 1. Chilean salmon production from 2005 to 2013. Data from SalmonChile.

Aquaculture in Chile is managed in production neighborhoods (or agrupación de concesiones para la salmonicultura – ACS). While initially focused in Region X (Los Lagos), only 36% of Atlantic salmon production now occurs there (176,500 mt) compared to 60% (287,000 mt) in Region XI (Aysen). Only 4% of Chile's Atlantic salmon production now occurs in Region XII (Magallanes)[3]. In contrast, the majority of coho (100,600 mt) is produced in Region X, compared to 47,000 mt in Region XI (Figure 2).

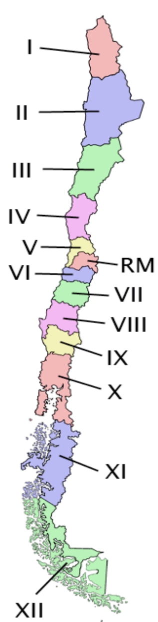

Figure 2. Regional Map of Chile (copied from Wikipedia.com).

[3] Sernapesca data quoted in Intrafish Jan 31 2014: Chile Atlantic Salmon production up 23% in 2013. www.intrafish.com

Import and export sources and statistics

According to the industry representative organization, SalmonChile[4], the US is the dominant market for Chilean Atlantic salmon exports, whereas Japan takes the largest share of coho salmon and trout. Figure 3 shows total export volumes and destinations from 2001 to 2011. The collapse in Chile's harvest volumes between 2007 and 2010 had a global impact on the dynamics of the farmed salmon markets.

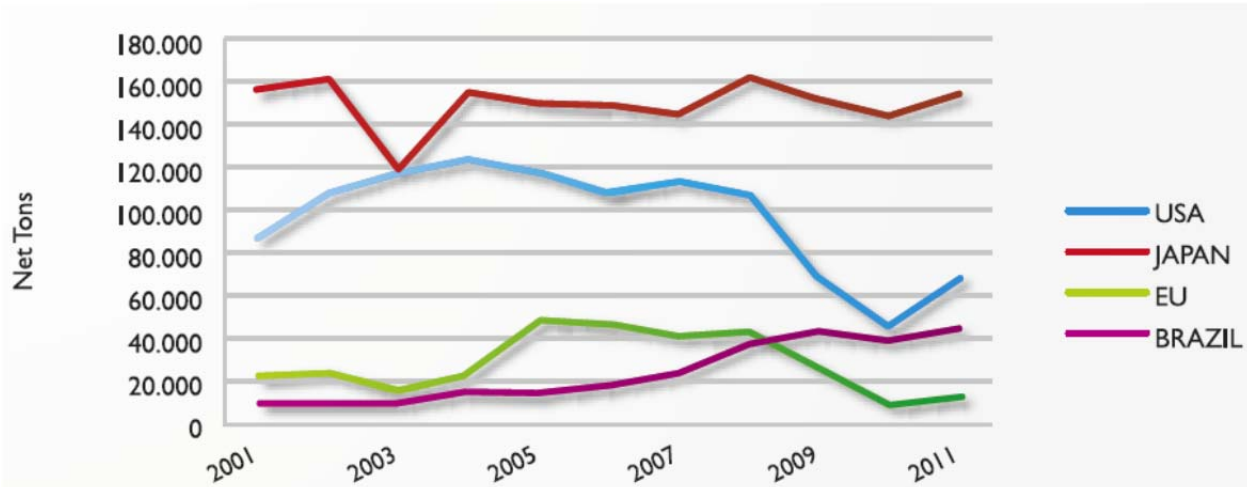

Figure 3. Farmed salmon exports from Chile from 2001 to 2011. Graph from SalmonChile (2014)[5].

Common and market names

Atlantic salmon

Coho salmon, Silver salmon

Packaging and product marketing may imply wild capture, but salmon originating from Chile on the U.S. market will be farmed.

Product forms

Chilean farmed salmon is available in all common fish presentations – whole, fillets, steaks, smoked, caviar, pate etc.

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[4] www,salmonchile.cl

[5] SalmonChile industry brief. Downloaded March 18 2014. http://www.salmonchile.cl/summary.php

Analysis

Scoring guide

- For criteria one to eight, all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional criteria (9X and 10X) result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here: www.seafoodwatch.org
- The full data values and scoring calculations are available in Annex 1.

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: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	7.5	7.5
Effluent	Yes	7.5	5
Locations/habitats	Yes	7.5	5
Predators and wildlife	Yes	2.5	0
Chemical use	Yes	7.5	7.5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	7.5	7.5
Source of stock	Yes	7.5	7.5
Other – (e.g. GHG emissions)	No	0	n/a
Total			**55**

C1 Data Final Score	6.1	YELLOW

It is clear that data availability from an industry perspective has improved considerably in recent years, but reliable monitoring of the environmental impacts of (for example) escapes, disease, parasites, cumulative nutrient losses, and antibiotic resistance, is still largely lacking. It

must also be emphasized that the majority of the industry data presented is collected and self-reported by the industry itself. On balance, the improved transparency of the industry and the availability of public data through Sernapesca and SIAC are to be congratulated, however, large knowledge gaps remain, particularly with respect to the industry's southward expansion. The final data score is a moderate 6.1 out of 10.

Justification of Ranking

Compared to other major salmon producing regions, Chile has until recently been considered to have relatively poor public data availability; (Buschmann et al. 2007) noted, "*Chile is now one of the world's largest aquaculture producing countries but has produced only an estimated 2% of the world's aquaculture environment studies."* Since then there has been significant academic research, particularly with respect to the collapse of the industry due to overproduction, weak regulation and ultimately disease from 2008 to 2011.

The industry association in Chile is SalmonChile: http://www.salmonchile.cl/index.php
The new website (March 2014) has very limited direct information, but links to relevant documents from Sernapesca and Subpesca. SalmonChile has published a management report for 2012-2013, but it contains no relevant information to this assessment. The SalmonChile website contains misleading information on the industry's total antibiotic use due to the selection of favorable years leading up to 2010 despite the public availability of data to the middle of 2013.

SalmonChile's technical organization is Intesal: http://www.intesal.cl/
Intesal has data and statistics on aspects of Chilean salmon farming, but does not allow public access beyond the industry members of SalmonChile.

The ISA crisis focused considerable attention on the industry and triggered a number of studies and reports, and greatly increased data collection and public reporting through the government's Subsecretaria de Pesca (undersecretary of fisheries) known as Subpesca and Servicio Nacional de Pesca (i.e., national fisheries service) known as Sernapesca.
Subpesca: http://www.subpesca.cl/institucional/602/w3-channel.html
Sernapesca: http://www.sernapesca.cl/index.php.

Operating under the governments Ministry of Economy, Development and Tourism, Sernapesca oversees the application of aquaculture regulation and production in Chile and publishes a number of reports online on a variety of subjects. Typically using data aggregated to a lesser or greater extent, the following are available.

- Site locations
- Environmental regulatory information (Reglamento Ambiental para la Acuicultura, RAMA)
- Sea lice data aggregated by region, ACS or concession
- Total antibiotic use, and breakdown by species and major disease
- Fish health information broken by species and disease

- Fish health regulatory information (Reglamento Sanitario para la Acuicultura, RESA)

Sernapesca now also operates a database known as SIAC (Sistema Integral de Attención Ciudadana) from which information can be made available on written request, often at a more specific level than the typically aggregated data available from the Sernapesca website. Information received from SIAC includes:

- Production figures
- Antibiotic use by type and percentage of total for each region from 2009 to 2012
- Distribution of disease outbreaks by region for 2009 and 2010
- Site specific monitoring data in terms of water quality and benthic condition (but not evidence of impacts beyond the farms, or cumulative regional impacts)

The Agriculture and livestock service (Servicio Agricola y Ganadero, SAG) has a list of veterinary medicinal products authorized for use in Chile:
http://www.sag.cl/Opensupport_faq/asp/pagdefault.asp?arginstanciaID=3&Temaid=21

According to (Thorstad et al. 2008) the Subsecretaria de Pesca has been compiling escape reports and these are available on request, however, such a request for this assessment only returned reported escapes to date in 2012 for region X1. Previous year's data were not available. This represents a key gap in public data availability in Chile. Predator mortality data are also not reported publically.

The Chilean government's environmental assessment service (Servicio de Evaluacion Ambiental, SEA), operates the System of Environmental Impact Assessment (SEIA), however, the database of information which it supports (including EIAs on salmon farm sites) is not accessible to non-Chilean citizens (i.e., not available to the buyers and consumers of Chile's farmed salmon).

Despite the improvements in data availability in Chile, the industry is still lacking in important environmental information. For example, there is no routine monitoring for antibiotic resistance, no systematic monitoring for sea lice pesticide impacts on non-target organisms, little understanding of the cumulative impacts and the carrying capacity for farms in the pioneering southerly regions. Additionally, there is very little monitoring of the impacts of farm pathogens and parasites, or escapes on Chile's native fish or broader ecosystems.

Scientific studies on Chilean salmon farming still appear somewhat limited compared to other major salmon production regions and, due to the rapid changes in the industry post-ISA, it is important keep the potential for change in mind when using older results. Furthermore, it is challenging to understand the impacts of the industries move into Chile's most southern Region XII, and again it appears necessary to use previous studies typically focused on the industry's initial expansion in Regions X or XI with caution.

Lastly, a commercial data and analysis company (Aquabench) also collects and collates useful industry data, and although of a commercial nature, public presentations of selected data enable their use in this analysis (for example Dempster & Kristianssen 2011).

Data Criterion - Conclusions and Final Score

On balance, the improved transparency of the industry and the availability of public data through Sernapesca and SIAC are to be congratulated, however, large knowledge gaps remain, particularly with respect to the industry's southward expansion. The final data score is a moderate 6.1 out of 10.

Criterion 2: Effluents

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: aquaculture operations 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 beyond the immediate vicinity of the farm.*

C2 Effluent Final Score	**2.00**	**RED**

Despite the large amounts of waste discharged directly into the environment from salmon farms in Chile, there is contradictory or inconclusive evidence of direct impacts beyond the immediate vicinity of the farm. The high production density, rapid expansion and limited study of salmon farming in Chile, in addition to uncertainties regarding the effectiveness of the regulatory system mean that the industry in Chile must be considered to be different from those in other major salmon farming regions. Therefore, despite more reassuring studies from other regions, numerous recent articles express concerns regarding potential cumulative impacts of soluble and particulate wastes from the large and rapid expansion of the industry in Chile. Ongoing questions regarding the effectiveness of the regulatory system with regard to the industry's continuing expansion further south into pristine habitats is also a frequently cited concern.

Yet the industry's production has rebounded rapidly since the ISA crisis and total production in Chile continues to increase rapidly with a corresponding increase in production in Region XI and a planned southward development into pristine habitats in Region XII. This combination of factors clearly necessitates an application of a precautionary principle and, according to the Seafood Watch criteria, there is a moderate-high concern of impacts beyond the immediate farm area and/or contributions to cumulative local or regional impacts. The final score for the Effluent Criterion is 2 out of 10.

Justification of Ranking

Salmon excrete both soluble and particulate wastes primarily as a result of incomplete digestion and absorption of their feeds. Although the salmon industry has increased efficiency and made significant reductions in nutrient loss per unit of fish production (Bureau and Hua 2010), these wastes clearly represent a substantial loss of the ecologically costly, and globally-sourced, feed ingredients and their discharge at farm sites represents a substantial point source of nutrients. In the Aysen region alone (Region XI), Niklitschek et al. (2013) estimated the

nutrient discharges from the salmon farms were equivalent to 12,300 mt of nitrogen and 1,600 mt phosphorous in 2010.

The majority of a salmon farm's effluents are soluble nutrients that are dispersed in the water column; salmonids excrete 75%–90% of their ammonia and ammonium waste across gill epithelia (Gormican 1989) or in concentrated urea (Persson 1988; Gowen et al. 1991). Nitrogen and phosphorus are also dissolved from waste feed and feces during and after descent to bottom sediments. Silvert (1994) suggested that 66%–85% of phosphorus in feed is lost in a dissolved form at salmon farms, and more recent figures from the use of similar feeds in Norway show the loss of as much as 70%, 62% and 70% of the total carbon, nitrogen and phosphorous (respectively) provided in the feeds (Wang et al. 2013). All these dissolved nutrients are available for uptake by the microbial community, phytoplankton or macroalgae (i.e., seaweeds, if farms are located close to shorelines or shallow areas). Particulate wastes (feces and uneaten food) settle on the seabed in an area controlled largely by the settling speed of the particles, the water depth and the current speed; as a result they generate a localized gradient of organic enrichment in the underlying and adjacent sediments (Black et al. 2008).

The Seafood Watch criteria assess the environmental impacts of these wastes in both the Effluent and Habitat Criteria as follows:

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

While the two criteria cover different impact locations, inevitably, there is some overlap between them in terms of monitoring data and scientific studies. The majority of this information will be presented in this Effluent Criterion, with the intent of minimizing (but not entirely avoiding) replication in the Habitat Criterion. Freshwater lakes are still used for smolt production in Chile and also have an effluent impact, but the scoring for the marine impacts below are consistent with the concerns for these environments. Further information is provided in Appendix 1.

Soluble Wastes

While basic data on water quality were provided by Sernapesca for all sites from the SIAC database (e.g., temperature, oxygen level, salinity), measurements of soluble nutrient levels beyond the farm were not included and are not measured or recorded as a common practice in Chile.

Brooks and Mahnken (2003) describe possible changes in the water column associated with the soluble nutrients from intensive culture of fish as:

- Eutrophication associated with nitrogen released across gill epithelia and in urine and feces
- The release of hydrogen sulfide and ammonia from underlying sediments

- Decreases in dissolved oxygen (DO) associated with salmon respiration and/or the oxidation of sedimented waste

As noted above, the release of ammonia and ammonium across the gills and in urea is the largest source of nitrogenous waste from salmon farms entering the water column. Olsen et al. (2012) show that soluble wastes from salmon farms are diluted and dispersed relatively rapidly in the water column, but are detectable hundreds of meters from the farms for extended periods of time. Several studies (from Scotland and other regions) have also reported the ability to detect farm-origin nitrogen at considerable distances from salmon or other fish farms, either directly measured in the water column or after uptake in seaweeds. For example, the chemical signature of salmon farm nitrogen was detected at 200 m in seawater (Sanderson et al. 2008), and from 1 km (Sanderson, 2006) up to 3-5 km (Karakassis 2005) in seaweeds. Venayagamoorthy et al (2011) concluded that under oscillatory (i.e., tidal) flow conditions, plumes of waste with relatively high concentrations occur at considerable distances from the source, although the absolute concentrations were low. However, these results are close to or at the limit of detection, and indications of measureable ecological effects beyond the farm (for example enhanced growth of seaweeds) are limited to much shorter distances on scales of tens of meters compared to reference sites at 150 m (Sanderson et al.2012, Troell et al. 1997, and FHL 2011). In contrast to these studies, Abreu et al. (2009) noted a high nitrogen uptake during the summer only in the seaweed *Gracilaria chilensis* at 800 m from a large Chilean salmon farm when experimentally located “in order to receive the main flow of nutrient discharges from salmon cage systems during the flood tides”.

According to Buschmann et al. (2006), in most locations in Chile, there have been no detectable increases in nitrogen concentration in the water column near salmon farms with the exception of the most heavily farmed areas. They concluded that, while excess inorganic nitrogen from salmon cages is available immediately for phytoplankton, the hydrodynamics of the site are the most important determinants of actual impact and only stagnant sites will exhibit increased phytoplankton biomass locally. Although Navarro et al. (2008) suggest that an increase in the heterotrophic microbial community (rather than phytoplankton) is the primary response to salmon farm effluent, changes to planktonic communities or associations with harmful algal blooms have been the general focus of the limited number of studies. The review by Buschmann et al. (2007) concluded that there is little scientific evidence, outside of limited laboratory studies and one field report from Chile, that nutrient loading from salmon farming is sufficient to initiate and sustain harmful algal blooms (HABs).

According to Niklitschek et al. (2013), despite the fact that the Patagonian fjords are relatively poor in nutrients, the enormous volumes of N and P released from fish farms have not provided evidence of measurable nutrient enrichments and/or detectable changes in pelagic ecosystems in surrounding waters. This can be compared to similar conclusions from British Columbia (Brooks and Mahnken 2003), and studies in Norway that show even in the most densely farmed region, the Hardangerfjord, all nutrient and chlorophyll-a values were within the high water quality thresholds set by the national authorities, and there were no indications

of elevated levels in the intermediate area of the fjord, which has the greatest density of farms (Husa et al. 2014b).

Despite the conclusions of Buschmann et al. (2007) quoted above, more recently the lead author, A. Buschmann, (University de Los Lagos, personal communication) reported that algal blooms had occurred in recent summers in Chile, and considered aquaculture to be a potential contributing factor. This agrees with recent studies (Iriarte et al. 2013, 2010) that note the Inner Sea of Chiloé, a major salmon producing region, is characterized by the occurrence of HABs mainly from micro-phytoplankton taxa such as dinoflagellates and diatoms. The HABs cover a wide region of the Patagonian marine ecosystem and, in addition to negatively affecting salmon farm production, may have ecological implications by influencing the biomass/nutrient ratio in the water column. Iriarte et al. (2013) suggest changes in the nutrient ratios (i.e., low silicon: nitrogen and high nitrogen: phosphorous ratios) of the coastal waters of the Patagonian fjords presently exposed to high levels of human activities (e.g., aquaculture, land change use, agriculture) could affect the phytoplankton species composition associated with HABs as well as the total phytoplankton biomass (i.e., from low to high). For example, according to Iriarte et al. (2013, and references therein) increased loads of nitrogen from anthropogenic activities in southern Chile (e.g., salmon cage farming) may potentially increase the nutrient ratios (e.g., nitrogen: silicon) in fjords and embayments, favoring the growth of non-silicified phytoplankton taxa at the expense of diatoms. However, other environmental changes, such as reduced freshwater flows, may also account for these variations. For example, Iriarte et al. (referencing Rebolledo et al. 2011) note that the increase of the diatom species *R. pungens* over the past 20 years has been suggested by the decrease in silicon flux (which would also increase the nitrogen: silicon ratio) associated with the long-term lower rainfall and river stream flow rates around the Inner Sea of Chiloé during this period. Iriarte et al. (2013) conclude, "The phytoplankton bloom dynamics, including those of HABs, despite their large impact on aquaculture health and environmental issues, remain an unanswered question and a major research challenge in coastal waters of the Patagonian marine ecosystem."

Iriarte et al. (2103) highlight the complexity of the region's nutrient dynamics and the challenge of attributing causes and effects due to salmon aquaculture. Niklitschek et al. (2103) reinforce the fact that these examples serve to illustrate the urgent and evident need to estimate actual carrying capacities of these water bodies before allowing a significant increase in the current farmed salmon production levels.

On a regional scale, Niklitschek et al. (2013) concluded that the risk of exceeding the ecosystem capability to incorporate nutrients into the food-web's carrying capacity is a matter of immediate concern. These authors note that no carrying capacity studies are available for the Aysen area, and the limited scientific research conducted there appears to be a major obstacle to reducing the environmental risks of this imminent expansion process. These aspects, in addition to the ongoing increase in production in Chile (Figure 1), will be discussed in greater detail below after considering the impacts of particulate effluent wastes.

Particulate Wastes

The impact on the seabed below the farm and within an allowable zone of effect is assessed in the Habitat Criterion, but any impacts beyond this immediate farm area or regulatory AZE are of relevance to this Effluent Criterion. Benthic monitoring data is therefore presented in the Habitat Criterion below.

Of the two waste streams (i.e., soluble and particulate), salmon farming impacts are considered to stem primarily from the latter as the release of particulate matter (feces and uneaten food) into the water column (Wilding 2011). In terms of the deposition of particulates, Keeley et al. (2013) describe the major pathways of biodeposition (Figure 4). This shows that of the total particulates leaving the net pen, some will dissolve or release nutrients before reaching the seabed; of the portion settling on the seabed in the primary area of deposition, some will be consumed directly by benthic organisms, some will accumulate and consolidate, and some will be resuspended 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.

The depositional footprint is controlled largely by the settling speed of the particles, the water depth and the current speed (Black et al. 2008). Keeley (2013) reports that at non-dispersive (i.e., depositional) sites, total deposition from the farm is almost entirely processed by settlement, assimilation by benthic biota, consolidation and ultimately burial—there is little or no influence from resuspension. In contrast, at dispersive (i.e., erosional) sites, settlement in the primary footprint (see Figure 4) is minimal and the impact is characterized by water column dilution and assimilation by biota with the additional influence of far-field deposition and subsequent assimilation and burial.

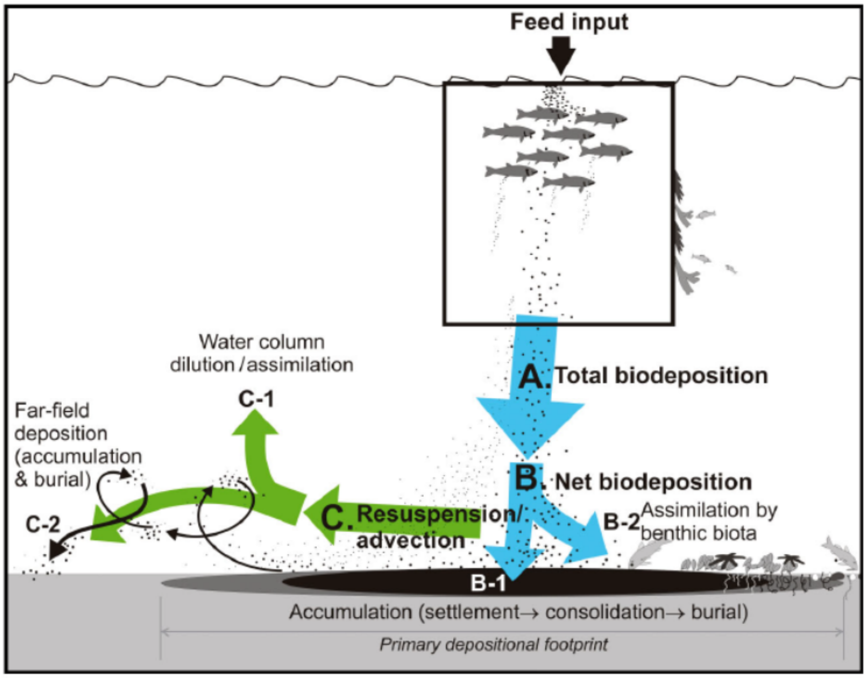

Figure 4. Summary of major pathways for salmon farm feed-derived biodeposition. A: total biodeposition = all waste particulates produced by the farm (feed and feces, ignoring dissolved organic component). B: net biodeposition includes the particulates that settle, accumulate and/or are used (assimilated) in the near field or 'primary footprint.' C: resuspension and advection includes the fraction of A that is exported from the immediate vicinity by currents. Image copied from Keeley et al. (2013).

Lander (2013) reported daily levels of particulate organic matter (POM) in the water column are higher at salmon farm cages (studied in east. Canada) than reference locations, and showed an increase in POM of 2 to 4 times over ambient levels adjacent to cages; however, they also reported a drop to ambient levels after distances of only 10 m from the net pens. The primary depositional area is typically localized and limited to the close proximity of the farm. Studies examining the spatial extent of fish farming impacts generally report that their effects on the benthic environment rapidly dissipate and decrease exponentially with increasing distance from their edge (Keeley et al. 2013; Chang et al. 2011; Mayor and Solan 2011; Mayor et al. 2010; Brooks and Mahnken 2003). Mayor et al. (2010) suggest that the immediate benthic impact of the fish farms examined extended to somewhere between 25 and 50 m from the cage edge, while Mayor and Solan (2011) reported that the effects of the fish farms examined in Scotland were only statistically discernible at less than 50 m from the cage edge.

Examples of additional field effects are available. For instance, Brooks and Mahnken (2003) reported detectable impacts at peak production at distances of between 90 and 205 m from the net pen perimeters, and subtle changes in macrobenthic communities have been documented to distances of 205 to 225 m downcurrent from salmon farms during peak production. Wilding et al. (2012) conclude that burrowers and suspension feeders were relatively resilient to salmon farms in muddy, sea-loch habitats in Scotland, but detectable impacts were noted at 100 m from the cage boundary. It should be noted that impacts at these

distances occur at peak production, are at the limit of detection, and are not evidence of significant changes to species diversity or abundance.

Studies specific to Chile show some conflicting results: Rudolph et al. (2009) concluded that although local changes occurred in the sediments, the mesoscale magnitude of the ecotoxicological alterations was small (although, unfortunately they did not include their definition of "mesoscale"), whereas Kowalewski (2011) showed salmon farms exerted a steep anthropogenic gradient where over a distance of 6 km the density of live shellfish declined by two orders of magnitude. Kowalewski concluded, "*This study provides a direct quantitative documentation of a catastrophic decline in local benthic productivity triggered by fish farming. Because benthic organisms purify aquatic habitats, support higher trophic levels, and sustain fisherman communities, shellfish extirpation has profound ecological and societal consequences."* In addition, Musclow (2005) showed sampling stations (sampled in 2003) within Pillan Fjord, which presented strong levels of ecological degradation and were grossly polluted with the exception of two stations located more than 1 km away from the actual position of fish farm cages; however, the authors note that Pillan Fjord is a shallow and enclosed fjord with limited water exchange.

A more recent study on the changes in depositional rates of nitrogen and carbon in the Comau Fjord in Chile over the last 100 years (Mayr et al. 2014) considered a doubling of deposition within the last two decades with respect to two possible scenarios: (1) in terms of recent climatic change in northwestern Patagonia possibly having lowered fluvial inflow into Comau Fjord and (2) in relation to anthropogenic eutrophication by rapidly expanding aquaculture. From 1995 to 2008, salmon production in this region increased from 1746 mt to 48,300 mt.

Figure 5 shows the rapid increase in autochthonous[6] carbon compared to a much smaller increase in allochthonous[7] carbon over the last two decades. As the accumulation of carbon from outside the fjord (allochthonous) remained fairly constant over a longer time period, Mayr et al. (2014) concluded that an increase in nutrients caused by aquaculture is the most likely explanation for the increased carbon and nitrogen accumulation rates in the last two decades in the Comau Fjord. (Note: the sampling in this study was not associated with the immediate area of any salmon farms.)

[6] Autochthonous – material formed or originating in the place where found
[7] Allochthonous - Material that is formed or introduced from somewhere other than the place it is presently found

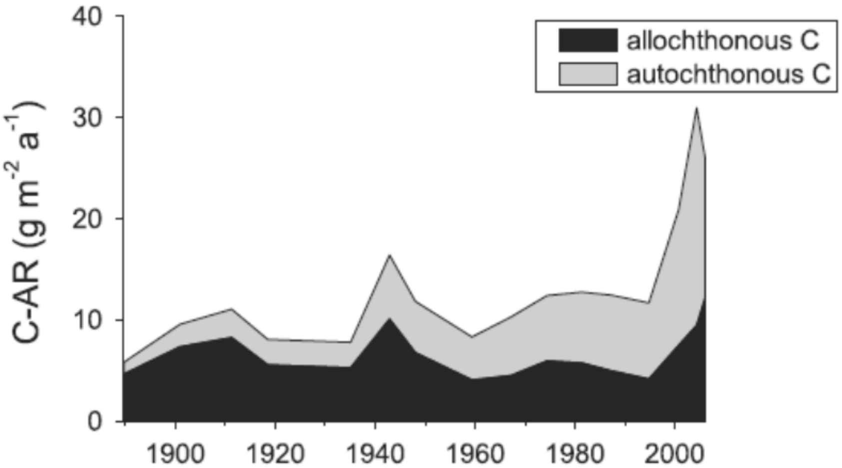

Figure 5. Mass accumulation rates of carbon in sediment cores during the last century. Graph copied from Mayr et al. (2014).

In a similar conclusion to that of Niklitschek et al. (2013) with respect to soluble wastes (i.e., noting the lack of carrying capacity studies), Mayr et al. (2014) concluded further studies are urgently needed to better quantify the sediment flux and anthropogenic impact on this unique Chilean benthic fjord ecosystem. The potential for local or regional impacts with respect to carrying capacity and cumulative impacts of both soluble and particulate wastes will be discussed below.

Carrying Capacity and Cumulative Impacts

It is generally considered that the Chilean salmon industry initially expanded in a poorly organized manner with higher-than-optimal density of farms, which led to concerns about deleterious environmental changes at the site level and cumulative impacts from multiple farms in the same area. For example in 2007, (Buschmann et al. 2007) stated, "*Salmon aquaculture in Chile is very different from its counterparts in northern parts of the world. Salmon farming in Chile is a highly concentrated activity where wastes from different farm sites have a much greater potential to interact, with potentially greater alterations to pelagic marine ecosystems, and possibly compromising rich, complex environmental systems.*"

According to Alvial et al. (2012), "*The industry's impressive technical and commercial success was not accompanied by matching research, monitoring and regulation to guard against foreseeable biological risks.*" Niklitschek et al. (2013) highlighted the rapid southward expansion of salmon farming into the pristine areas of the Aysen Region (XI) in the late 2000s (with a 42% increase in production between 2007 and 2009), and also noted that the longer term rapid growth of the salmon industry in Chile during the past three decades quickly overwhelmed the rather weak legal and institutional framework available to regulate this sector. Until 2010, a minimum distance of 2.8 km between farms was the only regulation that imposed some limitations to production density within water bodies (Niklitschek et al. 2013). Since 2010, new sanitary regulations that consider area-specific fallowing periods and density limits may help to reduce total nutrient loads within farm-clusters, however, according to Iriarte et al. (2010), precise estimation of the carrying capacity of the fjord systems (for aquaculture activities) and

the possible impacts of changes in the carrying capacity on ecosystems services is a major scientific challenge in this pristine region. Quiroga et al. (2013) also continue to express the concern that the regulatory framework in Chile has not developed the sophistication to monitor, evaluate and manage impacts in an effective manner as comparable to elsewhere in the world.

Niklitschek et al. (2013) extends the concerns of Iriarte et al. (2010), stating an urgent and evident need to estimate actual carrying capacities of these water bodies before allowing for a significant increase in the current production levels. In spite of the new regulations and practices, Alvial et al. (2012) also list some important issues that the industry and regulators have yet to address, including:

- Mechanisms to ensure that over-concentration of farming activity in certain areas is avoided
- Boundary definition of production zones
- Definition of zone carrying capacities

With respect to the Aysen area (Region XI), Nitlitschek et al. (2013) warn that while the new Chilean legislation has created some administrative tools that may allow the regulation of nutrient loads into specific areas, no carrying capacity studies are available for this area, and the limited scientific research conducted here appears, again, as a major obstacle to reducing the environmental risks of this imminent expansion process. These authors (Niklitschek et al. 2013) concluded that the risks of exceeding the ecosystem capability in order to incorporate nutrients into the food-web (carrying capacity) are a matter of immediate concern.

Yet despite these limitations, the industry continues to expand and move farther south apparently without understanding the potential impacts. Figure 6 shows the number of current aquaculture concessions (site licenses) in Regions X, XI and XII (as of 2011, from Dempster 2011), although it must be noted that these maps include sites for salmon, trout and shellfish aquaculture sites. Figure 6 shows salmon and trout farms operating in Aysen Fjords region between 1995 and 2011 (dotted line) and the production increase (shaded bars).

Alvial et al. (2012) acknowledge that this move farther south will impact previously pristine areas, and admit that the regional and smaller scale carrying capacities are still unknown. They state, "*The government is presently supporting studies to establish the dominant hydrodynamic characteristics of the regions on the basis for which it can then estimate carrying capacity in the salmon sea farming zones*."

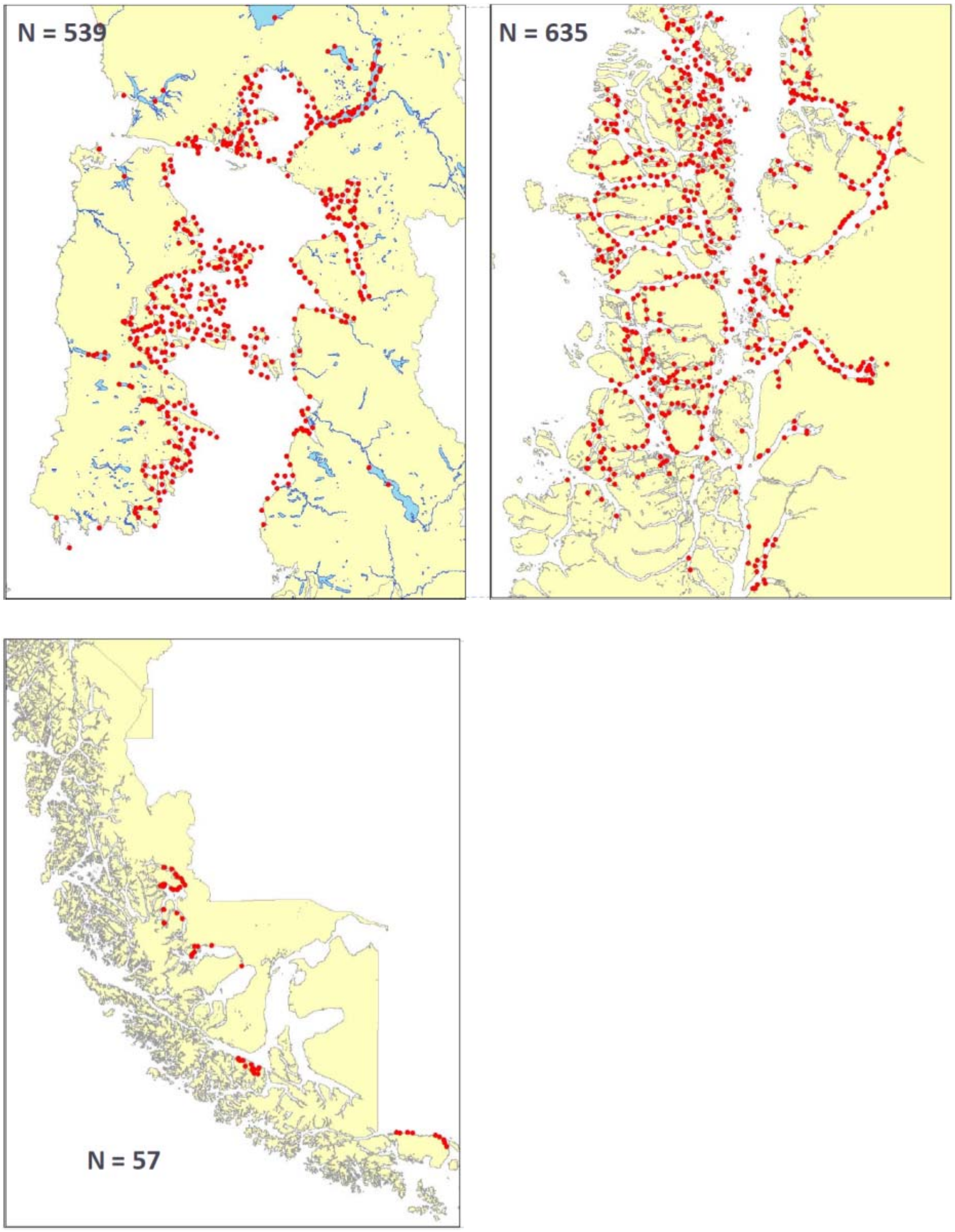

Figure 6. Current aquaculture concessions (site licenses) in Regions X, XI and XII (includes Atlantic and coho salmon and rainbow trout). Data from Aquabench, quoted in Dempster (2011). Note, not all sites are active at any one time.

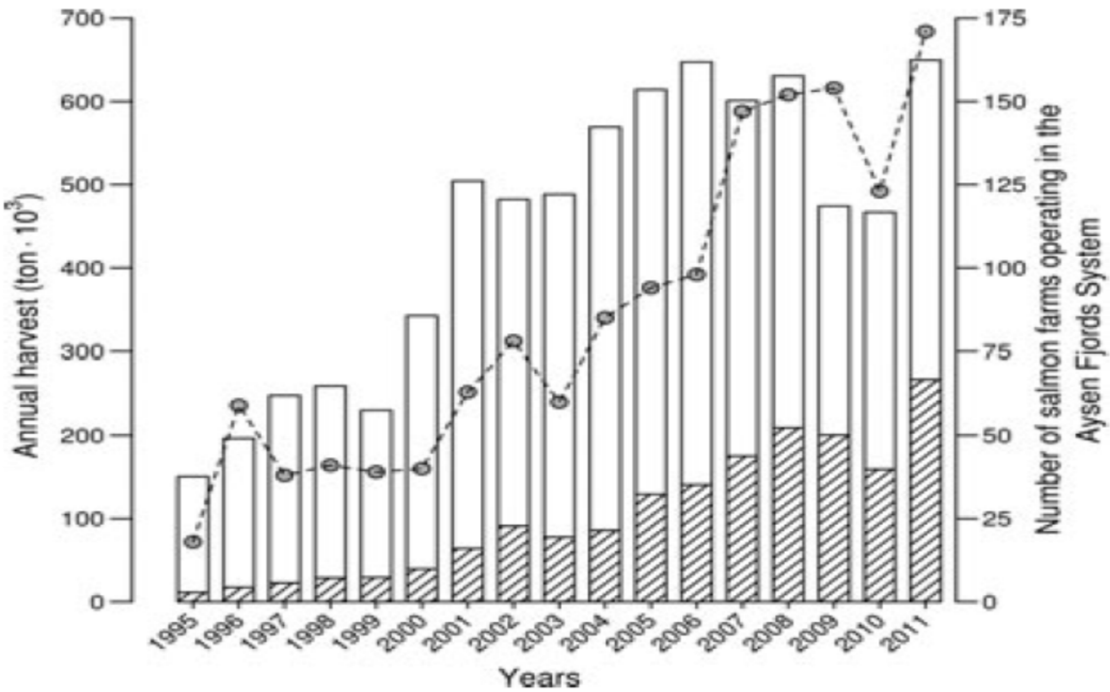

Figure 7. Annual harvest of salmonids in Chile (open bars) and in the Aysen Fjords System (shaded bars), and number of salmon and trout farms operating in Aysen Fjords System (dotted line) between 1995 and 2011. Graph copied from Niklitschek et al. (2013).

Both the industry and the Chilean government have made clear statements articulating plans for large increases in production in Chile (e.g., Jose Miguel Burgos of Undersecretariat for Fisheries, Jose Ramon Gutierrez of SalmonChile, Ricardo Garcia of Camanchaca (salmon producers); all were speakers at the Global Aquaculture Alliance GOAL meeting in Santiago, Chile (2011). According to industry media[8], a proposal for an additional 108 salmon sites in Region XII that are under environmental assessment (61 sites currently exist in Region XII of which 25 are operational) demonstrate the continued desire to expand farther south and to triple production in this region to as much as 100,000 mt in the Magallanes region.

Effluent Criterion - Conclusions and Final Score

The density, rapid expansion and limited study of salmon farming in Chile, plus the uncertainties regarding the effectiveness of the regulatory system mean that the industry can be considered to be different from those in other major salmon farming regions. Ongoing concerns and uncertainties regarding potential cumulative impacts from soluble and particulate effluent wastes beyond immediate farm areas, along with the uncertainty regarding the effectiveness of the regulatory system and the continued desire to expand production into pristine locations in Chile results in a moderate-high concern on the cumulative local or regional impacts in Chile. The final score for the Effluent Criterion is 2 out of 10.

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[8] Seafood.com June 4 2013: Chile to invest $250 million for 100 new farmed salmon sites in the sea lice-free Magallanes Region

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: Aquaculture operations are located at sites, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats.*

Habitat parameters	Value	Score	
F3.1 Habitat conversion and function		5.00	
F3.2a Content of habitat regulations	2.00		
F3.2b Enforcement of habitat regulations	2.25		
F3.2 Regulatory or management effectiveness score		1.80	
C3 Habitat Final Score		**3.93**	**YELLOW**
Critical?	NO		

The Habitat Criterion assesses the direct impacts on the farm area, which in the case of salmon farms is the seabed beneath the net pens and within a regulatory AZE. The channels and fjords of southern Chile have been shown to possess a unique benthic fauna of high ecological value. The floating net pens used in salmon farming have relatively little direct habitat impacts, but the impact on seabeds under them can be severe in intensity. Benthic monitoring data show approximately a quarter of Chilean marine sites do not meet the requirements of "aerobic" (i.e., good) conditions. The total impacts of all farm areas are limited to a relatively small spatial extent (approximately 1,300 hectares or 0.1% of the region's coastal border), and are relatively, rapidly reversible, but the industry's southward expansion has been, and continues to be, a cause for concern with continued uncertainty in the capability of the developing regulatory system. The high concerns regarding the larger spatial extent of habitat impacts due to effluents beyond the immediate farm area are covered by the red score in the Effluent Criterion, but the final score for the Habitat Criterion with respect to the immediate farm areas is 3.9 out of 10.

Justification of Ranking

The floating net pens used in salmon farming have relatively little direct habitat impacts, but the operational impacts on the benthic habitats below the farm and/or within an AZE can be profound.

According to Niklitschek et al. (2013), the southward expansion of the Chilean salmon industry in the Patagonian fjords has caused an increase in national and international concern about its

potential negative impact upon this pristine area, which holds a mosaic of unique ecosystems and three World Biosphere Reserves. This criterion assesses the loss of ecosystem services at individual farm sites in addition to the effectiveness of the regulatory system to manage potential cumulative impacts of multiple sites.

As noted in the Effluent Criterion, there is inevitably some overlap in the information used between the Effluent and Habitat Criteria for assessments of net pen aquaculture farms because the source of the impact is the same (i.e., uneaten feed and fish waste). The Seafood Watch criteria assess the environmental impacts of these wastes as follows:

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

Freshwater lakes are still used for smolt production in Chile and are considered to also have a habitat impact in these high value environments, but the scoring for the marine impacts below are consistent with the concerns for the freshwater environments. Further information is provided in Appendix 1.

Factor 3.1. Habitat Conversion and Function

Although the benthic communities in Chilean fjords only recently have been studied (Quiroga et al. 2013), there is no question that they are of high ecological value and, according to Molinet et al. (2011) and Quiroga et al. (2012) (both quoted in Quiroga et al. 2013), are very rich and diverse. The region is classified among those with the highest global conservation priority worldwide due to its threats and high degree of endemism (Iriarte et al. 2010), and the channels and fjords of southern Chile have been shown to possess a unique benthic fauna comprising endemic cold water corals, anemones and other species (Buschmann et al. 2006). These fjord ecosystems provide important services to humans, which according to Iriarte et al. (2010) have not been adequately measured and valued, and as a consequence, their ecosystem services are commonly ignored in public policy design and in the evaluation of development projects.

Of particular concern are a portfolio of forty areas of high conservation value (Áreas de Alto Valor de Conservación, AAVC) shown in Figure 8, established primarily by World Wildlife Fund-Chile. Comparing these high value areas (red colors) to the aquaculture sites mapped in Figure 6 above show relatively little overlap except for the central region of the inland sea. The species involved in defining the AAVC are varied, but this region includes cold-water corals which may be susceptible to salmon farm impacts.

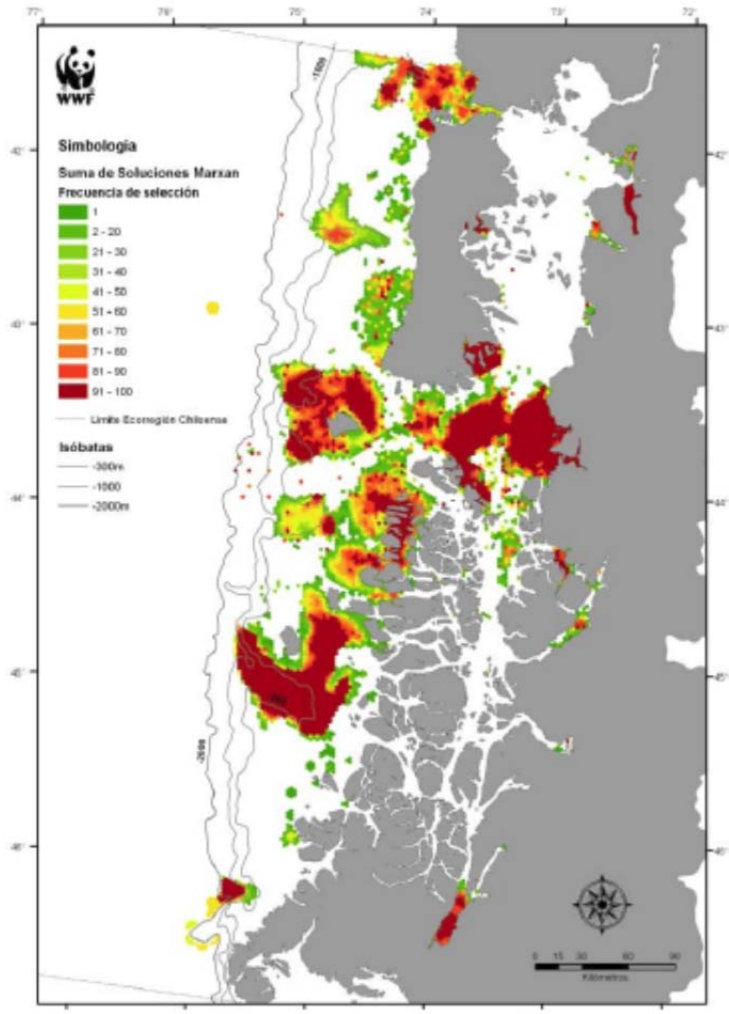

Figure 8. Areas of high conservation value. Darker red colors indicate areas of higher conservation value (WWF Factsheet 2011).

Intensive fish farming activities generate a localized gradient of organic enrichment in the underlying and adjacent sediments as a result of uneaten food and feces, and strongly influences the abundance and diversity of infaunal communities. In the area under the net pens or within the regulatory AZE, the impacts may be profound, but are now relatively well understood (see Black et al. 2008 for a review of these impacts). Primarily, changes can be anticipated in total volatile solids, redox potential, and sulfur chemistry in the sediments in the immediate vicinity of operational net pens, along with changes to the species composition, total taxa, abundance and total biomass (Brooks and Mahnken 2003). However, as noted in the Effluent Criterion, the effects vary according to the depositional or erosional nature of the site. Significant decreases in both the abundance and diversity of macrofauna are sometimes seen under farms located in depositional areas characterized by slow currents and fine-grained sediments, while net pens located in erosional environments with fast currents and sediments dominated by rock, cobble, gravel, and shell hash can dramatically increase macrobenthic production (Keeley et al. 2013).

Specifically in Chile, Soto and Norambuena (2004) found 2- to 5-fold higher mean concentrations of nutrients (nitrogen, phosphorus, carbon and particulate organic matter) and a nearly 50% lower species richness in sites below cages compared with control sites. Kowalewski (2011) documented a catastrophic decline in local benthic productivity triggered by fish farming, and Aranda et al. (2010) studied mats of filamentous bacteria covering the substrate below the cages and within the near field area from 10 to 60 m away (their sampling was done in 2006/7). Niklitschek et al. (2013) also note conflicting studies that have shown increased species richness around farm sites in Chile (Soto & Jara 2007), attributed to an edge effect that may be explained by increased productivity due to nutrient inputs and/or by enhanced protection (refuge) from small-scale fisheries that operate in the area

Basic results of benthic monitoring at the edge of all Chilean sites are available from Sernapesca[9] in a simple form of "aerobic" (i.e., good condition) or "anaerobic" (i.e., poor condition). Classification of the two states is dependent upon the results of a suite of indicators included in the Informes Sanitarios y Ambientales Acuicultura (INFA)[10] assessment, including pH, dissolved oxygen, redox potential, organic matter, macrofauna abundance, the presence of gas bubbles or bacterial mats, depending on the nature of the substrate type (e.g., soft or rocky). An analysis of all marine sites (Figure 9) shows the majority are in *Aerobic* condition, although the proportion has dropped every year since 2010. It is not known if this is a longer term trend. Twenty six percent of marine sites were in *anaerobic* condition, which subsequently require remediation to return to aerobic compliance conditions.

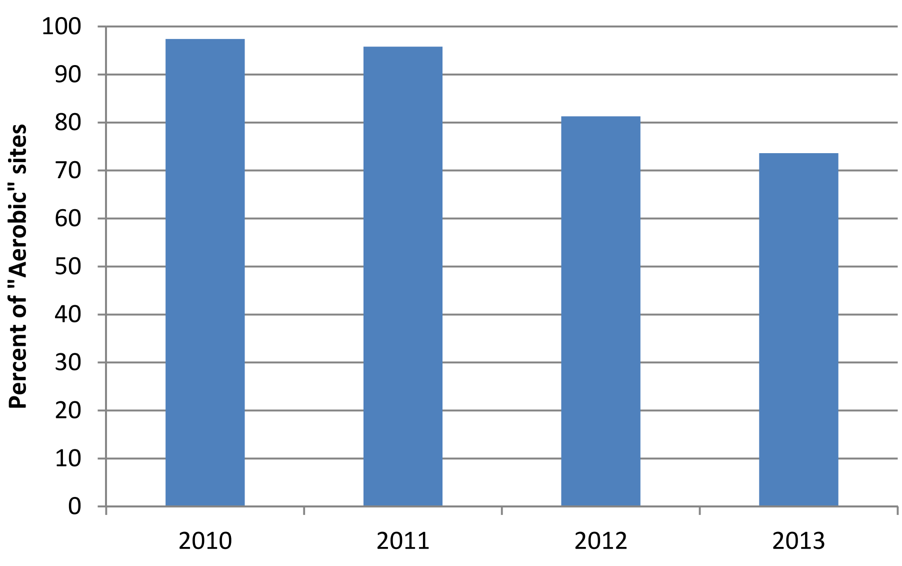

Figure 9. Percentage of "Aerobic" sites in Chile. Data from Sernapesca.

Focusing on the Aysen Region (XI), Niklitschek et al. (2013) indicate that local impacts can be severe in intensity, but to a relatively small spatial extent. They calculated that the region's 154

[9] http://www.sernapesca.cl/index.php?option=com_content&view=article&id=75&Itemid=205
[10] Translated as: Sanitary and Environmental Aquaculture Reports

sites covered 1278 hectares of area, or 0.1% of the region's coastal border. Given this relatively low proportion of the coastal surface area being impacted, the overall likelihood that these local effects added up to ecosystem-scale impacts seems low (according to Niklitscheck et al.). However, these authors note that this optimistic view must be qualified by considering two major issues: first, as salmon farms tend to be distributed in operational clusters, the actual proportion of the sea bottom being impacted within a bay, fjord or specific habitat may become much higher than average values; second, it is necessary to assess the relative importance of such specific habitats by considering their role in sustaining biological communities or species of special concern. Special attention must be paid to nursery areas and essential habitats for endemic species of restricted distribution (quoting Haussermann & Forsterra 2007).

Although it is clear that the ecosystem services have been lost in the areas below and close to the cages, the impacts are relatively and rapidly reversible compared to many other types of habitat conversion and can be recovered by fallowing and/or removing the farm. The time taken for full recovery is highly variable, but recovery is frequently substantial in 2 to 3 years (Black et al. 2008). In terms of the ecosystem services assessed in the Seafood Watch criteria, Macleod et al. (2008) reported that the main ecological functions in affected benthic habitats were re-established after 12 months (under Australian salmon farms). Therefore, although localized benthic impacts at existing sites may be severe, due to their rapid reversibility (i.e., a lack of irreversible impacts) and localized nature there is considered to be only a moderate habitat impact to the provision of ecosystem services at any one farm site. The initial score for Factor 3.1 would therefore be 7 out of 10. However, Chile is unusual among global salmon farming regions due to its continuing relocation and expansion of production in pristine habitats further south, particularly Region XII. It could be argued that the score should therefore be 2 out of 10 due to the ongoing loss of ecosystem services at these pristine sites, yet the potential for rapid recovery and an apparent lack of irreversible impacts appear to justify an intermediate score. A score of 5 is, therefore, selected to balance the relatively small total area impacted and the reversibility of impacts against the high ecological value of the areas affected, along with the ongoing expansion into pristine habitats. The cumulative impacts of Chile's multitude of sites and ongoing expansion to the south are assessed based on the effectiveness of the regulatory control in the following factors.

Factor 3.2. Habitat and Farm Siting Management Effectiveness (Appropriate to the Scale of the Industry)

As articulated in the Effluent Criterion above, it is clear that the development and expansion of Chile's salmon industry leading up to the production collapse in the late 2000s was not well regulated or managed. It is also clear that the collapse triggered a significant overhaul of the industry's management. Alvial et al. (2012) state, "*The epidemic* [ISA] *marked the end of a period where the industry's priority was production and sales and where government oversight and research did not keep pace with the industry's growth.*" A timeline of Chile's aquaculture regulations is provided in Figure 10.

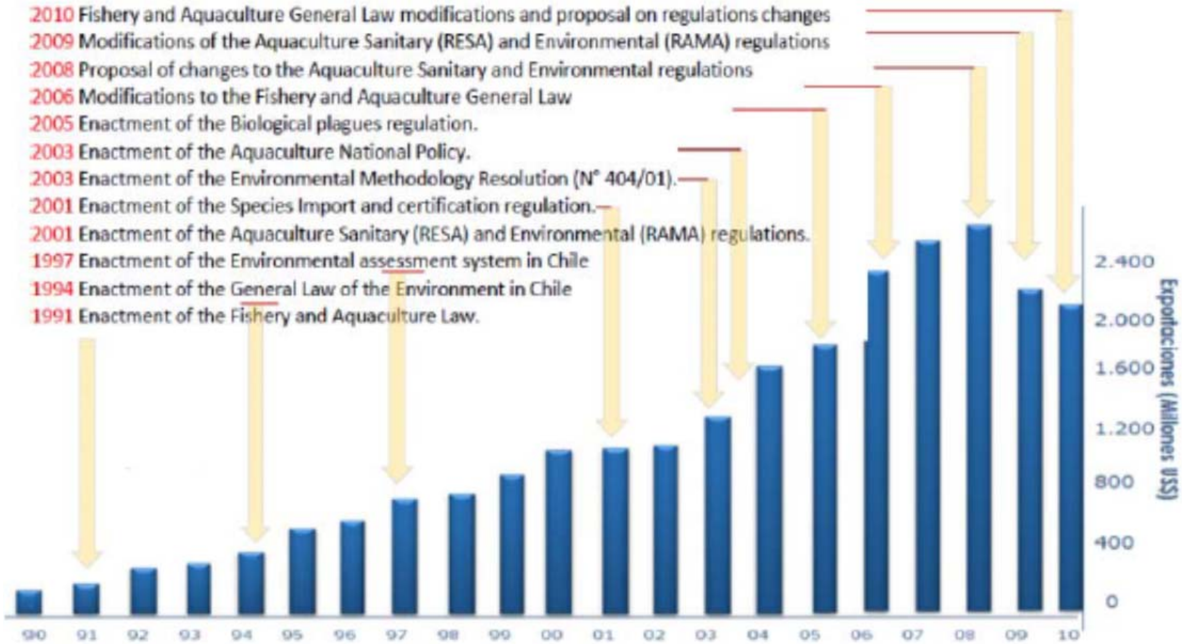

Figure 10. Timeline of Chile's aquaculture regulations in relation to total salmon production (exports), highlighting the recent changes in the regulations following the ISA crisis. Source Alvial et al. (2012).

However according to Quiroga et al. (2013), the regulatory framework in Chile has still not developed the sophistication to monitor, evaluate and manage impacts in an effective manner as comparable to elsewhere in the world. In general, environmental regulations are not based on empirical assessment of impacts and investigations on the effects of salmon farming on the benthic systems, especially in southern Chile, have been restricted to only few locations.

In relation to habitat impacts, the regulatory changes resulting from the ISA epidemic included modifications (in 2010) to the Environmental Regulation for Aquaculture (RAMA— established in 2001) to include new measures that strengthened the evaluation of benthic sediments under farms. All environmental monitoring now must be conducted by an independent entity approved and contracted by the Sernapesca and farms are required to meet the minimum standards otherwise sanctions are imposed (Alvial et al. 2012).

Specifically, the environmental indicators used to assess whether an aquaculture farm is operating within the biological capacity of its location include good water quality (reflected in levels of dissolved oxygen at or near saturation), and healthy benthic habitat conditions (i.e., toxic conditions in the first 2 or 3 cm, normal biodiversity and low hydrogen sulfide levels). Although the benthic data provided by Sernapesca (Figure 9) show that not all sites are in compliance, according to Alvial et al. (2012) the regulatory limits on pen density and the breaks in production from the enforced fallow periods will result in a reduction in waste build up in the environment. Other measures include limits to production in freshwater lakes, greater division of production into zones or neighborhoods, and relocation of farms to more appropriate locations (Alvial et al. 2012)—although this will in some cases mean pristine areas in more southern regions of Chile.

As discussed in the Effluent Criterion, the southward spread of industrial aquaculture in Chile from the initial focus on Region X (Los Lagos) into pristine environments further south in Chile's region XI (Aysen) and XII (Magallanes) has been a great cause for concern. Of particular concern are government supported studies that have not yet established the dominant hydrodynamic characteristics of the regions from which they can then estimate carrying capacity in the salmon sea farming zones (Niklitschek et al. 2013).

Assessing the effectiveness of regulatory enforcement is typically challenging. From an initial focus on capture fisheries, Subpesca and Sernapesca (as regulatory and enforcement agencies respectively) had to adapt to Chile's new and rapidly expanding aquaculture industry. Quoting Alvial et al. (2012), "*Since the development of salmon farming Sernapesca has been given new responsibilities, and has had to reorganize its departmental structure to reflect these changes in function, especially increasing inspection (Sernapesca 2009). Consequently, the agency's staff increased from 200 in 2007 to 729 in 2009, primarily in response to the ISA crisis and the new government regulations. Most recently, GLFA*[11] *No 20.434 (published in April 2010) created the Aquaculture Subdivision in Sernapesca and reinforced Subpesca's National Direction of Aquaculture. These two organizational changes were intended to strengthen the government's role in inspection and enforcement and distinguish aquaculture activities from fisheries activities.*"

While these changes and the availability of comprehensive benthic monitoring data from Sernapesca are encouraging, the ability of the regulations and enforcement to manage Chile's rebounding and projected future farmed salmon production remain somewhat unproven. As articulated in the Effluent Criterion, despite the generally optimistic tone in Alvial et al. (2012), these authors warn that there are still some important issues to address.

Scoring for Factor 3.2—assessing the regulatory content and effectiveness in Chile—is somewhat of a moving target. While there have been major improvements, the previous system was clearly unsustainable and it is yet to be proven that the current (new) measures can either robustly define ecologically appropriate limits (according to the value of the ecosystem services being affected in Chile) or enforce them robustly as production increases and expands farther south. Considering these concerns, precautionary scores are 2 (out of 5) for the content of regulations and 2.25 (out of 5) for effective enforcement.

Habitat Criterion - Conclusions and Final Score

Combining the farm level impact of 5 (out of 10) with the management and enforcement scores gives a final score of 3.9 out of 10. This reflects a moderate-high concern, but remains in the yellow category.

[11] GLFA – General Law on Fisheries and Aquaculture.

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: Aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and effectively control the frequency, risk of environmental impact and risk to human health of their use.*

Chemical Use parameters	Score	
C4 Chemical Use Score	**CRITICAL**	
C4 Chemical Use Final Score	**CRITICAL**	**RED**
Critical?	YES	

High chemical use has been a defining characteristic of the Chilean salmon farming industry since its inception. Antibiotic use in Chile is extremely high and increasing. Chile's estimated total antibiotic use in 2013 is currently more than 60 times the combined totals of the other three top global salmon producing regions of Norway, Scotland and British Columbia. The relative use in Chile in terms of grams of antibiotic per tonne of salmon production is 546 times that of Norway and 634 times that of Scotland. There are no regulations limiting their frequency of use, and the antibiotics used include those listed by the World Health Organization as highly and critically important to human health. Pesticide use in Chile is also extremely high, and approximate calculations show Chile uses more than one hundred times more pesticide per ton of production than British Columbia. The overuse of pesticides has led to the development of resistance to multiple treatments.

The extreme and increasing use of antibiotics and pesticides in Chile in terms of both total and relative quantities results in a critical score for the Chemical Use Criterion.

Justification of Ranking

Antibiotics

Since its beginnings, the Chilean salmon industry has exhibited an intense use of at least six antibiotics: oxolinic acid, amoxicillin, erythromycin, flumequine, florfenicol and oxytetracycline (Niklitschek et al. 2013). Although Ibieta et al. (2011) note that the average application rate of 0.46 kg antibiotics per ton of salmon production between 2005 and 2010 is the highest rate among the four main salmon producing countries (Norway, Chile, Scotland and Canada), an

analysis of more recent data in this Seafood Watch assessment shows that antibiotic use has increased dramatically since 2010.

Sernapesca provides figures on antibiotic use (for all aquaculture species) in Chile, and in annual reports provides a breakdown of the use-per-species and by dominant diseases. It is interesting to note that Millanao et al. (2011) indicate the unauthorized use of antibiotics means that the actual amount used may be higher than these reported figures.

Antibiotic use for Atlantic salmon for 2007 to 2013 (from Sernapesca 2012a, 2012b, 2013a) is shown in Table 1. Data for the first half of 2013 are available in Sernapesca (2013b) for total salmonids, therefore, the figure in Table 1 for Atlantic salmon in 2013 is estimated from a doubling of the quantity used in the first half of the year, and then multiplied by 0.62—the percentage (62%) of Chile's total aquaculture antibiotic use in 2012—which was applied to Atlantic salmon (as opposed to coho salmon or rainbow trout) according to Sernapesca (2012b). Total Atlantic salmon production figures are from the SalmonChile website[12].

Table 1. Antibiotic use (official data) in Chilean salmonid farming from 2007 to 2013. Data from Sernapesca and Salmon Chile as described in the text above. *the value for 2013 is estimated as described in the text.

Year	Quantity of antibiotics (tonnes)	Total Atlantic salmon production (mt)	Grams antibiotic per tonne of production
2007	250.7	331,042	757
2008	189.0	388,847	486
2009	60.2	203,067	296
2010	42.6	122,744	347
2011	105.5	264,354	399
2012	209.6	398,316	526
2013	343.6*	490,300	701

The results in Table 1 are plotted in Figure 10 and show the decrease in antibiotic use from 2007 to 2010 was largely owing to the drop in Atlantic salmon due to the ISA disease outbreak, but the use of antibiotics per ton of production also decreased over this period indicating that the remaining fish also were being treated less frequently. Since 2010, antibiotic use in Chile has increased dramatically both in terms of total use (increasing more than eight times since 2010), and in relative use per ton of production (more than doubling since 2010). Data for other species in 2012 show 8% of the total was used for coho salmon (approximately 27 mt), and 30% to rainbow trout (101 mt) (Sernapesca 2012b).

[12] http://www.salmonchile.cl/produccion.php

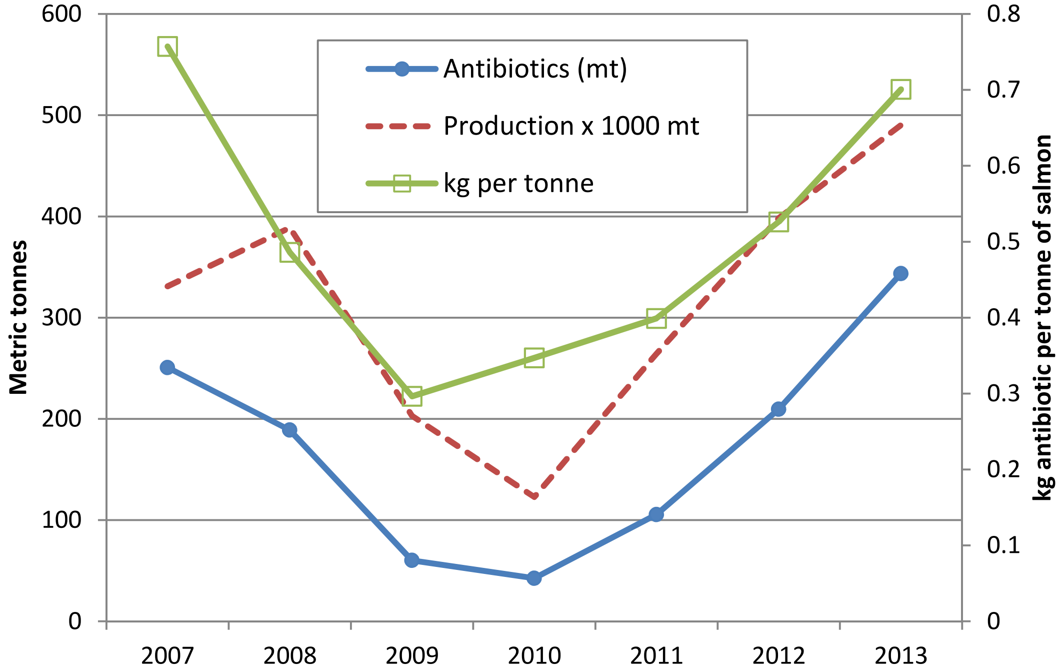

Figure 11. Antibiotic data from Table 1.

In comparison to other major salmon farming regions, Chile's use (both in terms of total and relative terms) is extremely high, and is on a steeply increasing trend. Chile's estimated total for 2013 is currently more than 60 times the combined totals of the other three top global salmon producing regions of Norway, Scotland and British Columbia (Norway used 1,591 kg in 2013, BC used 3,650 kg in 2012, Scotland used 168 kg in 2013, Chile used an estimated 342,600 kg in 2013). Accepting that the Chilean 2013 figure is an estimate, official Sernapesca figures for 2012 still represent nearly forty times as much as the combined totals of the other three regions (38.8 times). There are no regulation in Chile that limit the frequency of use of antibiotics, the total use at any one farm site, or the combined total use of areas, regions, or the industry as a whole.

The use per ton of production in Chile is also extremely high, and also on a steeply increasing trend. Figure 12 shows that Chile's use of antibiotics in terms of grams per tonne of production is 546 times that of Norway and 634 times that of Scotland (16 times BC).

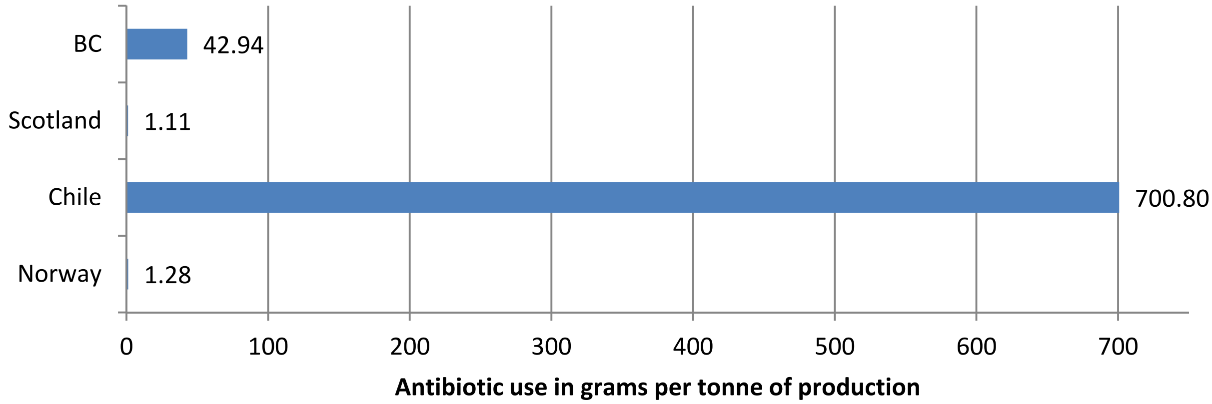

Figure 12. Relative antibiotic use in grams per ton of production for the four main production regions.

Despite the lower production volumes of coho salmon, antibiotic use for this species in 2012 (27 mt) is over five times the combined annual total of the other major global salmon producing regions.

In 2012, the following antibiotics were used in Chile Sernapesca (2012b):

- Oxytetracycline
- Florfenicol
- Amoxycilin
- Flumequin
- Erythromycin

In terms of quantities, oxytetracycline (43% of total) and florfenicol (54% of total) dominate, with flumequin, amoxycillin and erythromycin taking approximately 1% each. Fortt et al. (2007) report the presence of antibiotics administered to cultured salmon in commonly eaten wild fish in Chile (*Eleginops maclovinus* known as the Patagonian blenny, rock cod, or seabass, and the red rockfish, *Sebastes capensis*), providing what Gonzalez et al. (2011) consider unequivocal evidence of the interaction between farmed fish and free-living organisms.

Amoxycilin and erythromycin are listed as "Critically Important" for human medicine according to the World Health Organization (WHO 2011), and oxytetracycline is "Highly important." According to the Lancet Infectious Diseases Commission (Laxminarayan et al. 2013), within just a few years, we might be faced with dire setbacks, medically, socially, and economically as a result of antibiotic resistance unless real and unprecedented global coordinated actions are taken immediately. The same authors note that while many drivers of antibiotic consumption are based in human medicine, antibiotic use for disease treatment, growth promotion and disease prevention in agriculture, aquaculture, and horticulture is also a major contributing factor. Unnecessary antibiotic use in all sectors needs to be reduced and the spread to the environment minimized (Laxminarayan et al. 2013). Therefore, the use of antibiotics in open salmon farms is a source of concern.

Four review papers provide an excellent overview of the concerns relating to the development of microbial resistance to antibiotics, particularly in those organisms causing diseases in humans, and especially the development of resistance to chemicals critically or highly important to their treatment in humans (Cabello et al. 2013, Miranda 2012, Buschmann et al. 2012, and Smith 2008). Genetic components of resistance in microbial populations are naturally occurring (collectively referred to as the resistome[13]) and the pathways through which mobile elements (collectively referred to as the mobilome) can transfer through microbial populations and across species (e.g., from animals to humans) are well defined (Laxminarayan et al 2013). Although Miranda (2012) stated, "*there is currently no solid evidence available to demonstrate a direct link between the use of either antibacterial in fish farming and the occurrence of human pathogens resistant to that antibacterial agent,*" there appears to be very little research on the topic and, therefore, although the use of antimicrobials in salmon farming is lower than in terrestrial livestock, the additional selective pressure from using antibiotics highly important to human health in aquaculture remains a high concern.

Miranda (2012) also concludes, "*Further studies are necessary to understand how antibacterial resistance spreads among environmental microbiota and the ecological significance of the occurrence of multidrug-resistant bacteria in fish farm environments, but our current lack of knowledge on elements involved in these resistances emphasizes the necessity of maintaining a strict surveillance of emergence and spread of antibacterial resistance.*" In addition, Laxminarayan et al. (2013) state, "*A global system for surveillance of antibiotic use and resistance and its health and economic burden is urgently needed. Surveillance should include environmental sampling in addition to examination of clinical isolates.*" While it will be immediately clear from a veterinary perspective if resistance develops with respect to the clinical effectiveness of antibiotics to treat salmon diseases, monitoring of resistance in the environment is not currently carried out in Chile.

In Chile, Shah et al. (2014) tested bacterial isolates at salmon farms and at sites 8 km distant from farms, and found resistance to one or more antimicrobials was present in 81% of the isolates regardless of site. They concluded that high levels of antimicrobial resistance in marine sediments from aquaculture and non-aquaculture sites suggest that dispersion of the large amounts of antimicrobials used in Chilean salmon aquaculture has created selective pressure in areas of the marine environment far removed from the initial site of use of these agents. Henriquez-nunez et al. (2012) studied 40 Chilean salmon farm isolates of the bacterium *F. psychrophilum* and reported 90%, 92.5%, and 85% of the bacteria had developed resistant to three antibiotics oxytetracycline, florfenicol and oxolinic acid respectively. Although the hatcheries or farms cannot be definitively identified as the cause, these authors imply that the developed antibiotic resistance is likely to be due to the high amounts used, the repetitive use, and the use of much higher doses than those recommended

[13] Defined as the assemblage of chromosomal genes that are involved in intrinsic resistance and whose presence is independent of previous antibiotic exposure (Miranda, 2012).

As noted above, the severity of the global crisis of antibiotic resistance is not in dispute. For example the World Health Organization highlights an "urgent need for action" (WHO 2011), yet pragmatic solutions in food-producing animals are still somewhat undeveloped. For example, the United States Food and Drug Administration recently issued a "*Guidance for Industry*" document (FDA 2012) representing their "*current thinking on the topic.*" The WHO list of principles for responsible and prudent use (available in Appendix 1) identifies several requirements of best practice and the two strategies (WHO 2011 and FDA 2012) agree on the following two key points:

1) eliminating the use of antibiotics as growth promoters in food animals
2) requiring that antibiotics be administered to animals only when prescribed by a veterinarian

While it is noted that these documents relate primarily to terrestrial livestock, there is broad similarity with a number of other initiatives including the World Organization for Animal Health (OIE)[14], the Alliance for the Prudent Use of Antibiotics[15] (which supports the FDA's guidance), and in an aquatic context, the Responsible Use of Medicines in Agriculture Alliance's "Responsible Use of antimicrobials in fish production" (RUMA 2007).

With respect to antibiotic use in Chilean salmon farming, a food production system whose open nature leaves the fish inherently vulnerable to infections which then require treatment with highly-important antibiotics, does not appear to be prudent, judicious or justified. In addition, it can also be argued that prescribing veterinarians are often either employed by salmon farming companies, or cannot be considered independent from the needs and perhaps commercial incentives of the industry (point 9 of the WHO principles states: "*Economic incentives that facilitate the inappropriate prescription of antibiotics should be eliminated")*. Millanao et al. (2011) provide a comparative analysis of the amounts of antimicrobials consumed in salmon aquaculture and in human medicine in Chile, and report that it strongly suggests the most important selective pressure for antibiotic resistant bacteria in Chile is the excessive use in salmon farming.

Miranda (2012) provides a comprehensive review of the fate and persistence of antibacterial agents (including oxytetracycline) in salmonid farming, and it is clear that the antimicrobials used in aquaculture typically end up in the environment, regardless of the production system (even, potentially, in land-based closed containment hatchery systems, Lalonde et al. 2012). Figures vary by treatment type, but Cabello et al. (2013) estimate up to 80% of applied treatments can pass into the environment where they can accumulate in the sediments under and around the pens, or be carried by water currents to sediments at distant sites. The fate of these chemicals in the environment in terms of their accumulation, degradation, activity (or loss of activity when bound to organic matter), and their longevity is complex and somewhat contested, depending very much on the initial quantities applied and on the characteristics of the site.

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[14] OIE - Chapter 6.9 Terrestrial Animal Health Code - http://www.oie.int/index.php?id=169&L=0&htmfile=chapitre_1.6.9.htm

[15] http://www.tufts.edu/med/apua/news/policy_antibiotic_food_animals.shtml

Miranda's 2012 review highlights the complexity, firstly stating, "*The environmental effects of administering antibacterial agents in aquaculture are of great concern and include antibiotic resistance, residues in organisms and persistence in aquatic environments near salmonid farms."* But also added (with respect to oxytetracycline), "*In general terms, the real fate of antibacterials used in fish farming is an unsolved issue, mainly due to the studies that report a usual lack of correlation between the administered amount of oxytetracycline and the detected concentration in undercage sediments."* Miranda adds, "*Another aspect of great relevance to be considered is [….] the fact that various antibacterials are inhibited by certain environmental parameters,"* which include conditions in enriched sediments under fish farms.

Residues of some types of antimicrobials can remain in sediments for periods of over a year in locations where "large" amounts have been used and, despite their low toxicity and decreased activity when bound to organic matter in the sediments, antibiotics may affect the biological diversity of the phytoplankton and the zooplankton communities. These changes in diversity may potentially affect the health of animals and humans (Burridge et al. 2010). Christenssen (2006) also noted the potential for increased toxicity of multiple antibiotics if present at one location.

In summary, the extreme use of antibiotics in Chilean salmon farming and the documented concerns regarding the development of resistance clearly lead to a critical score for the Chemical Use Criterion.

Pesticides

The primary target of pesticides is the sea louse *Caligus rogercresseyi*, which Helgesen et al. (2014) describe as a major threat to Chilean salmon farming, but this species does not affect all salmonids in the same way. As articulated in the Disease Crietrion, Bravo et al. (2011) reported low numbers of lice on both coho and Chinook salmon in Chile. Therefore for this assessment, the dominant user of sea lice pesticides articulated below is considered to be Atlantic salmon (in addition to rainbow trout – not assessed in this report).

Increasing economic losses due to parasite infestations have led to the increased use of chemicals to control them (Molinet et al. 2011). Until 2007, emamectin benzoate was the only permitted treatment in Chile, but the massive use of this pesticide resulted in the dominant sea lice species along the Chilean coast evolving to become resistant to it. Fish farmers in Chile reported the loss of effectiveness of emamectin benzoate since the end of 2005 (Yatabe et al. 2011). The use of generic versions of emamectin benzoate and the poorly controlled oversight of its use (for example the varying concentrations of active ingredient used) are also considered to be involved in the development of resistance in Chile (Yatabe et al. 2011).

Bravo et al. (2013) demonstrated that as the industry moved south and expanded production in Region XI, a loss of sensitivity was observed in the region explained by the movement of salmon infected with *Caligus* from Region X to XI in 2006. The development of treatment resistance in sea lice has (with the exception of British Columbia) become problematic for salmon farming

regions around the world (Jones et al. 2013). Helgesen et al. (2014) also demonstrate resistance has developed to multiple sea lice treatments in Chile.

Increasing treatment failures led to alternative pesticides being authorized in Chile while the use of emamectin decreased. Data in Burridge et al. (2010) show the use of emmamectin benzoate dropped by over 50% between 2007 and 2008, while the use of deltamethrin and diflubenzuron increased by more than four times. More recent data provided by Sernapesca from the SIAC database showed that emamectin benzoate still represented 47% of treatments in 2009, but then dropped to only 20% of treatments in 2011. Over the same period cypermethrin (a bath treatment) increased from 0% in 2009 to 45% of all pesticide treatments in 2011. Table 2 shows the quantities of pesticides used and the changing treatment dynamics between 2009 and 2011.

Accepting the caveat that differences in toxicity mean that comparisons between treatments are subject error, British Columbia used a total of 18.7 kg of emamectin benzoate in 2011 (which dropped to 10 kg in 2012) (Data from DFO[16]). An approximate comparison of BC's relative use in terms of grams pesticide per ton of production to Chile's shows Chile used 126.9 times more pesticide per ton of production than BC in 2011.

Table 2. Total use of pesticides (in kg) across different treatments from 2009 to 2011. The massive increase in cypermethrin use is highlighted in yellow. Data provided by Sernapesca from the SIAC database. Note it is not relevant to compare numbers (i.e., quantities used) across treatments due to the varying toxicity and effective doses of different pesticides.

Year	Emamectin	Diflubenzuron	Deltamethrin	Cypermethrin
	In-feed treatments		Bath treatments	
2009	65	3878	3168	0
2010	47	3639	3430	593
2011	49	2815	3994	6832

The values in Table 2 demonstrate the changing fates of treatment effectiveness due to their overuse in Chile. For example, while the two in-feed treatments (emamectin and deltamethrin) decreased by approximately 25% between 2009 to 2011, total use of deltamethrin as a bath treatment increased by a similar amount while use of cypermethrin exploded from zero in 2009 to 6,832 kg in 2011 and increasing by more than 11 times between 2010 to 2011.

These pesticides are non-specific (i.e., their toxicity is not specific to the targeted sea lice) and, therefore, may affect non-target organisms, in particular crustaceans, in the vicinity of anti-lice treatments (Burridge, Weis et al. 2010). The two dominant treatment methods have different non-target threats: in-feed treatments where their metabolites can build up in areas where fecal matter and uneaten feed accumulate (primarily under the cages), and bath treatments where the water-borne plumes released from bath treatments (either in-cage or in a well boat) can affect non-target organisms over a wider area, particularly where multiple coordinated

[16] http://www.agf.gov.BC.ca/ahc/fish_health/antibiotics.htm,

treatments occur. Willis et al. (2005) concluded that Excis and Slice (cypermethrin and emamectin benzoate) do not adversely impact zooplankton communities, but a more recent review by Burridge et al. (2010) indicated that plumes of cypermethrin retain toxicity for a substantial period after release and concluded that single treatments have the potential to affect non-target invertebrates near cage sites.

In a review by Burridge et al. (2010), they concluded, "*Data generally suggest that negative impacts from anti-louse treatments, if they occur, are minor and will be restricted in spatial and temporal scale. However, published field data are rare.*" Subsequent to that study, research by the Norwegian Institute for Water Research (NIVA) investigated the increased use of diflubenzuron and teflubenzuron in Norway. Both of these pesticides had previously been used in Norway, but a voluntary ban on their use began at the end of the 1990s due to suspected adverse environmental effects. Langford et al. (2011) reported, "*The dissolved levels of diflubenzuron detected in water samples collected at the farms, and up to 1 km away, are sufficiently high to pose a risk to aquatic organisms.*" They also expressed concern that crab, shrimp and blue mussels are being exposed to both diflubenzuron and teflubenzuron and noted a potential risk to shrimp could reasonably be extrapolated to any species that undergoes molting in its lifecycle.

Burridge et al. (2010) add a concern about cumulative impacts of multiple treatments from multiple farms stating, "*No studies (lab or field) have adequately addressed cumulative effects. Salmon farms do not exist in isolation*." A key strategy of sea lice management is the increased use of coordinated area treatments during which time the likelihood of cumulative impacts from multiple treatments on multiple farms in the same area appears to be greatly increased.

Chemical Use Criterion - Conclusions and Final Score

High chemical use has been a defining characteristic of the Chilean salmon farming industry since its inception. The extreme, and increasing, use of antibiotics in terms of both total and relative quantities in Chile, and the inevitable concerns with respect to the development of resistance produce a critical score for the Chemical Use Criterion. This results in an overall red recommendation for Chilean salmon farming.

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: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the non-edible portion of farmed fish.*

Feed parameters	Value	Score	
F5.1a Fish In: Fish Out ratio (FIFO)	2.43	3.92	
F5.1b Source fishery sustainability score		-6.00	
F5.1: Wild Fish Use		2.46	
F5.2a Protein IN	260.3		
F5.2b Protein OUT	169.0		
F5.2: Net Protein Gain or Loss (%)	-35.1	6	
F5.3: Feed Footprint (hectares)	11.67	6	
C5 Feed Final Score		**4.23**	**YELLOW**
Critical?	NO		

Fishmeal and oil inclusion in Chilean salmon feeds continues to be replaced by increasing levels of alternative crop protein or oil ingredients. Feed company data show that from first principles (i.e., ignoring other uses of associated fishmeal) 2.43 tonnes of wild fish would need to be caught to produce one tonne of farmed salmon. Improved data availability on the sources of fish oil and their oil yields could improve this value (i.e., reduce it). There is a net edible protein loss of 35.1%, but the inclusion level of crop and land animal ingredients in Chilean feeds results in a moderate total feed footprint of 11.67 hectares per tonne of production. The final feed score is 4.23 out of 10.

Justification of Ranking

Specific data have been provided by one large feed company in Chile, which wishes to remain anonymous. On the basis that this information is unverified and may not be fully representative of the whole industry, FAO data for Chile from 2010 (Tacon et al. 2011) is also considered. Although it is likely that processing and pellet consistency may be different for different salmon species, for the purposes of this assessment, the formulations are not considered to be significantly different (Gavin Hastings, Skretting Canada, personal communication date?). This is

supported by Tacon et al. (2011) who group Atlantic, coho and Chinook together in their feed composition data.

Factor 5.1. Wild Fish Use

This factor combines an estimate of the amount of wild fish used to produce farmed salmon with a measure of the sustainability of the source fisheries.

Table 3. Feed marine ingredients composition data.

Parameter	FAO data	Feed company data
Fishmeal inclusion level	20-25% 22.5% used	22%
Percentage of fishmeal from by-products[17]	Not specified (0% used)	15 %
Fishmeal yield (from wild fish)	Not specified (22.5% used)	23 %
Fish oil inclusion level	15 %	11 %
Percentage of fish oil from by-products	Not specified (0% used)	15 %
Fish oil yield (from wild fish)	Not specified (5% used)	Not specified (5% used)
Economic Feed Conversion ratio (FCR)	1.3	1.3
Calculated values		
Fish In : Fish Out ratio for fishmeal	1.3	1.06
Fish In : Fish Out ratio for fish oil	3.9	2.43
Seafood Watch FIFO score (0-10)	**0.25**	**3.92**

The fish oil inclusion level drives the FI:FO ratio for salmon, but the two data sets show significantly different FI:FO values primarily due to the inclusion level of fish oil and the use of fish oil from byproducts, which are not specified in the FAO data. While it is considered likely that the feed companies will use some fish oil from byproducts, Chile itself is a minor producer of byproducts fishmeal and oil (Tacon et al. 2011). The use of byproduct ingredients in aquaculture feeds is generally increasing (Tacon et al. 2011) and, therefore, it is assumed that the feed company data most accurately represent the current situation. In addition, due to the considerable consolidation in the salmon industry, feed production in Chile is considered to be dominated by three feed companies: EWOS, Biomar and Skretting. Therefore, the risk that the data provided by any one feed company is dramatically different from a country average is considered relatively small. This also supports the use of the feed company data for the final values.

[17] While it can be argued that byproducts of wild caught fish processed for human consumption (heads, guts, skin, fins etc.) have the same ecological cost of production as the fish fillets that humans value as food, the current socially logical use of byproducts to grow more food (farmed fish) means that they do not currently contribute to the FIFO scores.

Therefore, the final FI:FO value of 2.43 means that from first principles (i.e., ignoring the additional fishmeal produced), 2.43 mt of wild fish would need to be caught to produce one ton of Chilean farmed salmon. In 2008, Tacon and Metian reported the decreased use of fishmeal and oil in salmon feeds over previous years, and predicted a continuing future decline in their use. The FI:FO value presented in this assessment is very much in line with their predictions of 3.0 in 2010, decreasing to 2.0 in 2015, but these values still remain high compared to many other farmed species. The FI:FO value of 2.43 translates to a relatively low score of 3.92 out of 10 in the Seafood Watch criteria.

Source fishery sustainability

The sustainability of the source fisheries provides an adjustment factor, which applies an increasing negative penalty to the FI:FO score. The criterion assumes that using sustainable fisheries is the minimum acceptable baseline (zero penalty) and applies an increasing penalty for the use of increasingly unsustainable fisheries. Although the FAO report (Tacon et al. 2011) identifies Chile as a major producer of fishmeal and oil, due to the global commodity nature of fishmeal trade and use, it does not enable the robust identification of sources of fishmeal actually used in Chilean salmon feeds.

The feed company data specifies anchovy *(Engraulis ringens*), sardine (*Strangomera bentincky*), and jack mackerel (*Trachurus murphyi*) as the species used. According to Fishsource[18],there are several scores below 6 for different aspects and regions of these fisheries indicating significant problems with the stock health or fishery management[19]. This would initially result in a -8 penalty factor, however, these fisheries are largely certified under the IFFO Responsible Sourcing scheme[20] which although not a dedicated sustainability scheme improves the penalty to -6.

Final Wild Fish Use score

The -6 penalty is applied to the FI:FO score (according to the FI:FO value), and results in a final Wild Fish Use score of 2.46 (out of 10). This remains a high conservation concern.

Factor 5.2. Net Protein Gain or Loss

Feed company data are presented in the table below. The FAO data (Tacon et al. 2011) specify “plant protein sources” as 25% of the feed, and “animal byproducts” inclusion at 10%–20%. Assuming “animal byproducts” are primarily protein ingredients (as was the case for 2008 FAO data in the same report), it can be concluded that the contribution to total edible protein of the different ingredient groups would be similar between the two data sets. Due to its completeness, the feed company dataset is used to derive the scores in this assessment.

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[18] www.fishsource.com

[19] Anchovy – Chilean III and IV one score <6 for advice. Regions V-X 3.8 for fishers comply, 4.2 for stock health Southern Peru – 0.4 for management advice

The Chilean Jack mackerel has a score of 1 for stock health, and 4.3 for following management advice.

No information available on Fishsource for sardine.

[20] IFFO RS certification list accessed July 20, 2012 at http://www.iffo.net/downloads/IFFO%20RS/Approved%20plants%2015062012.pdf

Table 4. Protein composition data.

Parameter	Feed company data
Protein content of feed	39%
Percentage of total protein from non-edible sources (by-products etc.)	40.9%
Percentage of protein from edible sources	59.1%
Percentage of protein form crop sources	27.1%
Feed Conversion ratio	1.3
Protein INPUT per ton of farmed salmon	260.3kg
Protein content of whole harvested salmon[21]	16.9 %
Edible yield of harvested salmon	62.3%
Percentage of farmed salmon by-products utilized	100%
Utilized **protein OUTPUT** per ton of farmed salmon	169 kg
Net protein loss	-35.1%
Seafood Watch score (0-10)	6

The results show that despite improvements in feeding efficiency, salmon farming remains a substantial net loss of edible protein (-35.1%) and scores 6 out of 10.

Factor 5.3. Feed Footprint

By considering the grouped inclusion levels of marine, terrestrial crop and terrestrial land animal feed ingredients, this factor provides an approximate guide to the ocean and land area used per ton of farmed salmon. Data provided by the feed company shows 33% of the feed ingredients are marine origin, 38.7% are from crops, and 23% are from land animals (that also required crops for feed). The remainder (approximately 5%) is considered to include vitamin and mineral premixes, antioxidants and processing aids etc.

Table 5. Feed ingredient categories.

Parameter	Feed company data
Marine ingredients inclusion	33 %
Crop ingredients inclusion	38.7 %
Land animal ingredients inclusion	23 %
Ocean area (hectares) used per ton of farmed salmon	11.16 ha
Land area (hectares) used per ton of farmed salmon	0.52 ha
Total area (hectares)	11.67
Footprint score (0-10)	6

The area values calculated by the Seafood Watch criteria are broadly similar to the 0.33 ha of land area and 11.5 ha of ocean per ton of edible product calculated by Nofima (2011) for Norwegian salmon, and imply that Chile's 2011 farmed salmon production of 285,000 mt utilized the primary productivity of approximately 4.3 million hectares of ocean and over 200,000 hectares of agricultural crop land.

[21] Nofima (2011), quoting unpublished marine harvest data

Due to the substantial use of terrestrial crop and animal ingredients, the feed footprint is moderate (a high use of marine ingredients leads to a larger total footprint), and scores 6 out of 10.

Feed Criterion - Conclusions and Final Score

The final feed score is calculated from the average of the three factors with a double weighting for the Wild Fish Use factor. Despite the reduction in the use of marine ingredients, the wild fish use score is still quite low. In addition, salmon farming remains a resource intensive operation as indicated by the substantial net loss of protein. However, the increasing use of terrestrial ingredients means that the footprint score is moderate-good and the final feed score is 4.23, which is in the moderate (or yellow) category.

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: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Atlantic salmon

Escape parameters	Value	Score	
F6.1 Escape Risk		2.00	
F6.1a Recapture and mortality (%)	13		
F6.1b Invasiveness		6	
C6 Escape Final Score		**4.00**	**YELLOW**
Critical?	NO		

Coho salmon

Escape parameters	Value	Score	
F6.1 Escape Risk		2.00	
F6.1a Recapture and mortality (%)	13		
F6.1b Invasiveness		4	
C6 Escape Final Score		**3.00**	**RED**
Critical?	NO		

Data on escapes is not readily available in Chile, but although the construction of net pens has improved, known escape events in Chile and other salmon farming regions highlight the fundamental weakness of the production system and the ongoing high risk of escapes. Data on recaptures and mortality are also unavailable, but due to poor feeding success, particularly in Atlantic salmon, mortalities are likely to be high. Although a non-native species, Atlantic salmon do not appear to feed successfully after escape, and are not considered successful colonizers in Chile, thus, they are considered highly unlikely to establish populations in Chile. Coho salmon appear to be partly established with the capacity to increase their range, and do appear to feed on native prey. Combining the escape risk with an invasiveness score final scores for Atlantic salmon of 4 out of 10, and for coho salmon, 3 out of 10.

Justification of Ranking

The Escapes Criterion estimates the escape risk (modified by evidence of recaptures or mortality), and combines it with the risk of impact (i.e., the invasiveness) of the species involved.

Factor 6.1a. Escape Risk

According to Thorstad et al. (2008) the Chilean Government (Subpesca) has been compiling reported escapes and these data are available on request. A request was made as part of this assessment, but only reported escapes for an unspecified period of 2012 in Region XI were provided; data from other years were not available. This partial data showed that there had been two large reported escapes of Atlantic salmon in 2012 of 37,476 and 32,448 fish.

In general, it is considered that the likelihood of escape in the region (along with all other salmon farming regions) continues to be relatively high. For example, WWF-Chile (2009) showed that large escape events happened in 2007, 2008 and 2009 (with over 1.5 million fish escaping in 2007 and 2008). Despite significant efforts to improve cage design and management, large escape events continue to occur in all salmon farming regions. Another example shows 154,569 salmon escaped in Scotland in a single event in February 2014, (Scottish-Government 2014[22]), in 2010, 15,763 fish escaped in British Columbia (Marine Harvest Canada, personal communication 2012), and two escapes of more than 175,000 fish in Norway in 2011[23] were reported in industry media but do not yet show up in official statistics. During field visits in 2011, anecdotal conversations also indicated the potential for deliberate sabotage of nets and theft of fish, which is likely to lead to potentially significant escapes of farmed fish. Other anecdotal information[24] indicates that theft of salmonids in Chile reaches almost 5% of total production. One method of stealing fish involves cutting nets, which leads to a high risk of escape.

Thomassen and Leira (2012) stated that large-scale escape events have been a characteristic of the development of the industry in Chile and conclude, "*There is still much room for improvement in relation to verified structural design procedures and computerized tools for structural analysis* [of sea cages] *and, to a large extent, they can be regarded as not being in accordance with the state-of-the-art of structural analysis and design for more traditional types of marine structures*." In addition, there is considerable doubt about the accuracy of reported escapes. For example, the ability to accurately count fish into and out of the cages and, therefore, to account for escapes is limited and, therefore on this basis alone, the accuracy of escapes data is questionable. According to Bisson et al. (2006), it is "*quite likely that the number of fish claimed by salmon farmers to have escaped is underestimated,"* and examples from other regions support this reality. For example, with reference to industry reported escape figures, the Norwegian Seafood Federation FHL (2011) also states, *"many varying figures are based on guesswork and more or less plausible estimates."*

Freshwater hatcheries and smolt units are a further source of escapes, primarily for coho salmon whose smolts are still produced in lakes and estuaries. Schröder et al. (2011) (referencing Sepulveda et al. 2009) implied the regular low intensity leakage of fish from

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[22] http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish/18364/18692/escapeStatistics

[23] www.intrafish.com 27 September 2011 "Salmar escape: a tiny affair"

[24] Gozalo Mendez of Mendez & Company, interviewed in Aqua.cl http://www.aqua.cl/entrevistas/entrevista.php?doc=312

freshwater hatcheries is an insidious source of invasive salmonids in Chile that is seldom reported and goes largely unnoticed. WWF (2007) reported that over the last 25 years, salmon farming has contributed significantly to wild salmonid populations through massive losses of individuals from farms in freshwater systems where the first stages of development (from ova to smolts) are carried out. The recent switch for Atlantic salmon from cages in lakes and estuaries to tank-based contained systems (see criterion 8) should mean that this is no longer a problem for this species.

Piccolo and Orlikowska (2012) proposed the frequency and magnitude of escape events might be expected to decrease as industry practices improve, but concluded that due to the nature of salmon farming, large accidental escapes are likely to continue to occur sporadically. Although nearly all salmon producing countries have established routines for reporting large-scale escapes, the magnitude of unreported escapes is unknown and information on low-level leakage from cages and escapes from freshwater hatcheries remains uniformly poor (Thorstad et al. 2008). In Chile, the recurrent presence of escapees (species not defined), even in the absence of massive escape events, has been explained by small but frequent operational leakages from local farms (Niklitschek et al. 2011a).

The limited data from 2012 and examples of large escapes from similar production systems in other regions highlight the fact that large-scale escapes continue, and even ignoring the likelihood of a high number of unreported "trickle" escapes, the very high numbers of fish held in any one cage, combined with the inherently vulnerable and high-risk system means that there continues to be a high risk of significant escapes. The efforts being made by the industry to reduce escapes in all salmon farming regions are commendable and reduce the escape risk from high to moderate-high in the Seafood Watch criteria (2 out of 10). This score can improve if and when it can be demonstrated (i.e., robust data are made available), with long-term confidence, that improvements to the production system and management have reduced the risk of large-scale and ongoing trickle escape events.

Recaptures and Mortality

There are no data available on recaptures of escaped salmon in Chile. Observed occurrences of "wild-caught" Atlantic salmon in local markets indicate some level of recaptures, but (as mentioned above), anecdotal conversations indicate that some of these fish may have been deliberately released or stolen from farms. The Chilean legislation also mandates the existence and application of contingency plans to manage escape events at each farm, but there is a lack of sufficient incentives or sanctions to stimulate relevant recapture efforts (Niklitschek et al. 2013).

Information on the direct mortality of salmon in the escape area is conflicting. This may be due to poor clarifications in relevant studies as to the species involved. For example, data collected following a catastrophic escape event in Chile suggest farm raised salmon (species not defined) feed on wild prey and maintain positive growth rates (Buschmann et al. 2009). However, according to Soto et al. (2001) (in Thorstad et al. 2008) the Atlantic salmon is apparently unable to adapt to the Chilean marine environment and feed itself, which is reflected in a 42%

incidence of empty stomachs, possibly leading to individuals starving to death. This is supported by Niklitschek et al. (2011) who reported 71% with empty stomachs, and also by a review in British Columbia by Noakes (2011) who reported that of 1,584 recaptured salmon in BC (where the species is also non-native), 80% of them had empty stomachs, leading the author to conclude, *"Most escaped Atlantic salmon do not successfully feed and survive for any extended period of time*."

Norwegian information compiled by Glover et al. (2012) also indicated high mortality of escaping farmed salmon. Yet the 2006 references on which this conclusion is based now form part of a broader literature showing highly variable survival of escapees linked to the size and age at escape, the location, the time of year, along with a combination of factors leading to predation susceptibility (Skilbrei et al. 2010; Skilbrei & Jorgensen 2010; As Arismendi Hansen & Youngson 2010; Whoriskey et al. 2006; and Olsen & Skilbrei 2010). As Arismendi et al. (2012) conclude that Atlantic salmon may be less successful in the wild in the Pacific than in their native Atlantic, it is not possible to draw any robust conclusions to the situation in Chile from studies within the specie's native ranges (i.e., Atlantic salmon in the Atlantic and coho salmon in the North Pacific).

In conclusion, there is insufficient evidence to strongly justify a specific recapture and mortality score, even though while the former (i.e., recaptures) is considered to be minimal, the latter (mortality) is likely to significantly reduce the number of escapees leaving the escape locality. Some adjustment of the escape risk score seems justified with respect to mortality, therefore, while maintaining the score in the "high" risk category on a precautionary basis, the escape risk score is improved from 2 to 3 (representing approximately 13% mortality) to acknowledge potentially significant direct mortalities in the farm area. The final escape risk score, therefore, is 3 out of 10 and remains a high concern.

Factor 6.1b. Invasiveness

Atlantic salmon is a non-native species in Chile. Schröder & Garcia de Leaniz (2011) and references therein conclude that the encroachment of salmonids is one of the biggest threats to native fish biodiversity in Chile. De Leaniz et al. (2010) report exotic salmonids have caused widespread ecological damage, particularly to native fish fauna. Both escaped and feral salmonid populations may play multiple roles simultaneously as predators, competitors and/or prey of native populations and pre-existing naturalized salmonids, such as rainbow and brown trout (Soto et al. 2001). In these references and others, "salmonid" refers to a number of species, and present a challenge to interpreting the impacts of Atlantic salmon or coho salmon within discussions concerning the "salmonid" group in general.

For example, without specifying the relevant species, Buschmann et al. (2009) state, "*Data collected following a catastrophic escape event in Chile suggest farm raised salmon feed on wild prey, maintain positive growth rates, and reduce the abundance of native marine fish species through competition and/or predation (Soto et al. 2001). In the coastal rivers of southern Chile, farm escapes are common and stomach content analysis reveals they frequently feed on freshwater prey. Recently evidence of natural reproduction has begun to accumulate, though it*

remains unknown how escapes and their offspring might impact the native freshwater fish of southern Chile." In contrast, Thorstad et al. (2008) and Arismendi et al. (2012) conclude that the Atlantic salmon is apparently unable to adapt to the marine environment in Chile, supporting similar conclusions in British Columbia (Noakes, 2011).

Deliberate introductions (governmental and private) of a number of salmonid species have been attempted over extended periods since the 19th century (Niklitschek et al. 2013, and references therein), particularly of brown and steelhead trout, but also of Chinook, chum, coho, cherry, and pink salmon, coho salmon, chum salmon. Ranching efforts for the salmon species were more recent, from the 1970s to the 1990s. As a result, Chinook salmon has invaded the whole Patagonian area of southern Chile, but no conclusive evidence has been documented in the Aysen region of recent colonization by escapees from any of the three farmed species (Niklitschek et al. 2013 and references therein).

For comparison, it is clear that rainbow trout and brown trout have become widely established in Chile, and are associated with the significant impacts on native fish species highlighted by De Leaniz et al. (2010). Chinook salmon are successfully reproducing and rapidly extending their range in the wild in Chile, however, these species (i.e., various trout species and Chinook salmon) have become established primarily from deliberate introductions and ranching programs rather than from aquaculture escapes (Arismendi et al. 2012). Coho salmon has also been the subject of ranching programs in the past and seems to be reproducing in the Aysen region where mature individuals are found returning to local rivers (Niklistcheck & Aedo 2002) and, according to WWF-Chile (2009), there is evidence of wild coho salmon populations in several southern Patagonian rivers. Yet although adult escapees of Atlantic salmon have been found in Chilean streams (Young et al. 2009; Schröder et al. 2011), the evidence for the establishment of this species in Chile is very sparse and inconclusive. For example, Schröder et al. (2011) concluded the free-living juvenile salmon in their study river were possibly the offspring of naturally reproducing Atlantic salmon, though as this has not been reported in Chile yet (Arismendi et al. 2009), they could have been fish of hatchery origin that escaped at a very early age.

According to WWF-Chile, research indicates that while the number of Atlantic salmon released to the environment can be sufficient to produce reproductive populations, most of them do not survive to reach this stage (Soto et al. 2001 and 2006 in WWF-Chile 2009). In general, Arismendi et al. (2012) concluded that Atlantic salmon show little evidence of establishing self-sustaining populations and thus may be considered less successful in the wild. It is not known if further domestication and adaptation to the conditions in Chile will result in Atlantic salmon becoming more likely to establish over subsequent generations, or less likely due to further reductions in their ability to survive outside the farm environment. The ongoing escape of varying life stages of Atlantic salmon (previous deliberate attempts to establish them have focused only on juveniles) into pristine environments as the industry expands hundreds of miles further south into different environmental conditions may also increase any potential for establishment.

The primary concern in Chile and elsewhere in the Southern hemisphere has been impacts on native galaxiid fish. According to De Leaniz et al. (2010), "*Across the southern hemisphere, exotic salmonids directly impact on native galaxiids by reducing their foraging efficiency, limiting their growth, restricting their range, forcing them to seek cover or to use suboptimal habitats, and also by preying upon them.*" Again, without defining the species within the salmonid group, Niklitschek et al. (2013) (and references therein) show that escaped salmonids can impose a strong predatory pressure upon schooling fish, including two small pelagic species of importance to artisanal fishermen, such as southern sprat and Chilean silverside, and to a smaller extent, upon juvenile Patagonian grenadier, a key resource for the local fishing industry.

Of the three main farmed salmonids, Niklitschek et al. (2013) estimated lifetime averaged consumption rates of 13.8, 7.9 and 3.8 g per day for escaped coho, steelhead trout and Atlantic salmon in Chile (incorporating an assumed high mortality from the 71% found with empty stomachs in Nikltischek et al. 2011), and based on large historic escapes between 2004 and 2009, calculated an upper limit of consumption of 6,600 t of pelagic prey from local ecosystems.

Although Atlantic salmon companies have now predominantly moved away from using Chile's freshwater lakes for smolt production to tank-based systems on land, production of coho smolts continues in lakes (predominantly in Region X) according to data from Sernapesca[25]. The biogeographical isolation and the distinctive environmental characteristics of Chile's freshwater systems have resulted in a unique ecological composition with very high levels of endemism, but unfortunately over 90% of the native fish are currently listed as threatened (Leon-Munoz et al. 2007). These authors state, "*It is clear however, that the ecological interactions of these* [native endemic] *species have changed markedly as a result of productive activities such as salmon farming carried out in freshwater bodies.*"

According to the Seafood Watch criteria, it is considered that coho are "*partly established with the potential to extend the species range or coverage,*" whereas Atlantic salmon is considered to be: "*not established, and highly unlikely to establish viable populations*." Coho appear to compete with and prey on wild species, whereas Atlantic salmon have low feeding success. As a non-native species with poor performance outside its native range, Atlantic salmon have an invasiveness score of 6 out of 10, whereas coho salmon with evidence of establishment and ecological impacts, have an invasiveness score of 4 out of 10).

Escapes Criterion - Conclusions and Final Score

The final escapes score (which combines the escape risk score with the invasiveness score) is 4 (out of 10) for Atlantic salmon and 3 for coho (and Chinook).

[25] Data provided on request from the SIAC database

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 waterbody*
- *Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Pathogen and parasite parameters	Score	
C7 Biosecurity	4.00	
C7 Disease; pathogen and parasite Final Score	**4.00**	**Yellow**
Critical?	**NO**	

Disease has been a defining characteristic of the expansion of salmon farming in Chile, particularly the collapse in Atlantic salmon production from 2009 to 2011 due to the ISA virus. Monthly mortality rates are typically between 0.5% and 1.5%, and dominated by the bacterial pathogen *Piscirickettsia salmonis.* Unlike other major salmon farming regions, Chile does not have important wild salmon populations and, although there is evidence of infections of wild fish by parasitic sea lice, there is no evidence of significant mortalities in wild fish in Chile. The expansion of the industry into pristine areas further south represents a cause for concern, and the final score for the Disease Criterion is a precautionary 4 out of 10.

Justification of Ranking

Despite the widely publicized commercial impacts of the Infectious Salmon Anemia virus (ISA) on salmon production in Chile, understanding the impacts of this and other farm-origin pathogens and parasites on wild populations in Chile continues to be challenging. For example, while the presence of the ISA virus in Chile is broadly considered to be associated with the development of salmon farming in the region (Kibenge 2011), the virus itself was not identified in 502 samples of local fish, mollusks, crustaceans, sea lion feces, and microplankton, and the only positive result was from a free-living Atlantic salmon escapee (Gonzalez et al. 2011). ISA is also not known to have caused mortalities in any wild populations of salmon (NOAA 2012). On this basis, it seems unlikely that this particular virus has any significant impact on wild fish populations.

Sernapesca's publically available[26] annual health report of marine farm sites (Informe Sanitario De Salmonicultura En Centros Marinos) provides a comprehensive annual review of the causes of mortality for salmonids farmed in Chile. Monthly mortality figures of Atlantic and coho salmon range from approximately 0.5% to 1.5%, and Figures 13 and 14 below show the

[26] http://www.sernapesca.cl/index.php?option=com_remository&Itemid=246&func=fileinfo&id=8014

dominant causes of mortality in both species. The dominant pathogen is *Piscirickettsia salmonis,* which causes Salmon Rickettsial Syndrome (SRS) and is a leading cause of antibiotic use in Chile. ISA mortalities are now low; a non-pathogenic strain of ISA (ISA-HPRO) now appears dominant in Chile, but could mutate to a more virulent form (Godoy et al. 2013) as indicated by occasional recurring outbreaks of ISA disease (Sernapesca 2014).

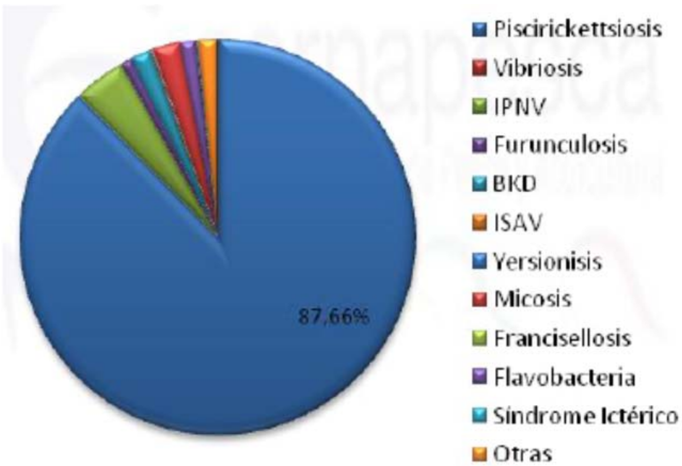

Figure 13. Causes of mortality for Atlantic salmon in marine farms in Chile inn 2013. Chart copied from Sernapesca.

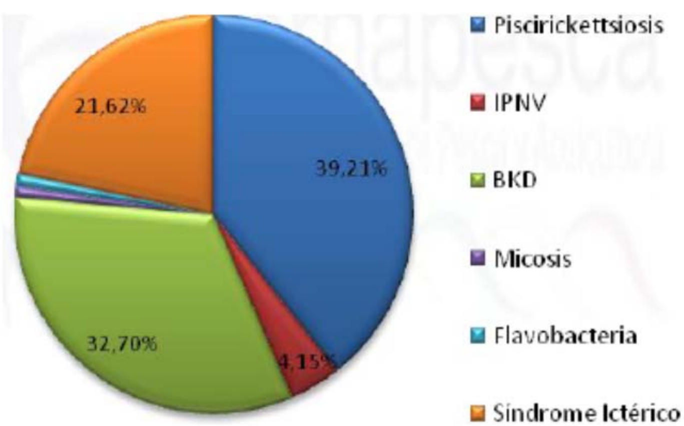

Figure 14. Causes of mortality for coho salmon in marine farms in Chile inn 2013. Chart copied from Sernapesca.

In many cases, salmon in open net pen farms are initially infected by pathogens or parasites associated with local native fish populations, but due to the scale of farm operations they do have the potential to be a substantial point source of retransmission of the same pathogens (and potentially more virulent strains of those pathogens) to the same, or other, wild species (Rimstad 2011). Further complicating a simple "snapshot" assessment of the ecological impacts of pathogens and parasites in Chile are the recent changes to regulations and management practices that occurred after the ISA outbreak in 2007/8 (reviewed in Alvial et al. 2012). Understanding the real impacts that these changes are having on farm biosecurity and any interactions with wild fish populations due to parasites and pathogens is also challenging. Wild

fish populations may carry these pathogens but be less susceptible to clinical disease outbreak without the stress associated with the farm environment.

In terms of overall impacts on wild species, Rimstad (2011) stated, "*With the possible exception of salmon lice, there are few reliable data sets on the distribution of fish pathogens in wild populations, and the knowledge of interactions with wild reservoirs is thus limited.*" This recent paper continues to confirm the findings of the Salmon Aquaculture Dialogue Technical Working Group's global review, which came to the same conclusion (Hammell et al. 2009).

It is clear that sea lice are a major production problem for salmon farm management in Chile, perhaps most clearly indicated by their association with the ISA outbreak, and also by the resistance to pesticide treatments that has developed due to their overuse in efforts to control their numbers (see the Chemical Use Criterion). Even though there are well-studied interactions with important wild salmonid populations in other major salmon farming regions (e.g., Norway, Scotland and British Columbia), the impacts on the native wild species in southern Chile (where there are no wild salmonids) are very poorly studied. This is also complicated by the fact that sea lice studies in the other major salmon farming regions focus on the salmon-specialist sea lice *Lepeoptheirus salmonis,* whereas the species of greatest concern in Chile, *Caligus rogercresseyi*, is a non-specialist and can be hosted by (and therefore potentially have an impact on) a range of native species.

Perhaps the most informative study is Sepulveda et al. (2004) which compared the parasites of wild and farmed fish and the potential infection vectors between them. Of nine species of ectoparasites (external) and 21 species of endoparasites (internal), an overlap between wild fish and farmed salmon was only demonstrated for two parasites (the sea lice *Caligus rogercresseyi*, and the nematode worm *Hysterothylacium aduncum*). While it is assumed that native fish species such as the rock cod "Roballo" (*Eleginops maclovinus)* were the original source of the sea lice infections on the farm, this species sheds this parasite during migration to estuaries and rivers in the fall, and regains the infection when returning to the sea in spring. While this means Roballo may be able to avoid serious impacts, it is farmed salmonids that have now become the source of infection of sea lice in this native species (Sepulveda et al. 2004).

According to Bravo et al. (2011), a wide range of wild fish have been identified as natural hosts of *C. rogercresseyi*, and these species are frequently found in the vicinity of salmon farming cages, often attracted by surplus feed, but despite this evidence of (re)infection of wild fish in Chile, there is no evidence of physiological impacts of lice infections on wild fish in Chile nor, therefore, of their potential population-level impacts. While infection is generally always considered to have a negative physiological impact, it may not directly lead to mortality, yet research on parasite interactions with wild fish in British Columbia highlights the potential for significant secondary impacts such as increased risk of predation on infected individuals (Krkosek et al. 2011).

The increasing farm biomass in more southern regions is also increasing the parasite burden in these previously pristine areas, as sea lice number increase there (Sernapesca 2011). Bravo et

al. (2011) reported that *C. rogercresseyi* was recorded for the first time in Chile on Atlantic salmon in the Puerto Montt area (Region X), but are now widely distributed in Region X and have spread south to Region XI. Sea lice numbers remain low in Magallanes (Region XII) where salmon production is currently at low levels (Sernapesca 2011), but it seems likely that numbers will increase as production expands there unless temperatures are too low. Bravo et al. (2011) (and references therein) report that sea lice are unable to complete development through to the adult stage on coho, and the levels of lice reported on coho and Chinook are very low. Although the limited data presented here indicate a lesser concern than Atlantic salmon, it is somewhat relative and remains unclear in reality.

Disease Criterion - Conclusions and Final Score

Although disease has been a defining characteristic of the development of salmon farming in Chile, and a variety of pathogens are still prevalent on farms, there is very little evidence of significant impacts on wild fish in Chile. The potential impacts of the expansion of salmon farms (as pathogen reservoirs) into more southerly locations are as yet unknown. Therefore, a precautionary score of 4 out of 10 is applied as the production system is open to the introduction of local pathogens and may amplify their numbers and/or increase their virulence, and is open to their subsequent discharge.

Criterion 8: Source of Stock – Independence from Wild Fisheries

Impact, unit of sustainability and principle

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

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	100	
C8 Source of stock Final Score	**10.00**	**GREEN**

Justification of Ranking

Due to the industry-wide use of domesticated broodstocks, the Chilean salmon farming industry is considered to be independent of wild salmon fisheries for the supply of adult or juvenile fish. The score is 10.

Criterion 9X: Wildlife and Predator Mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife

This is an "exceptional" factor 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.

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**-4.00**	**YELLOW**
Critical?	NO	

The primary concern for predator mortalities is the southern sea lion for which lethal control is illegal. While some mortality may be permitted and/or may be unreported (and data are not available), the numbers are considered unlikely to have a significant impact on the population size. The score for penalty score for this criterion is -4 (out of -10).

Justification of Ranking
Salmon farms in Chile's southern regions are likely to interact with a wide variety of marine and avian life (Miethke and Glavez 2009 and references therein) described Chile's Chiloense (Region X) and the channels and fjords (Region XI) as an extraordinary biodiverse marine area, home to a number of endemic and rare species, such as the Chilean dolphin, and with a richness of marine invertebrates. It contains critical habitat for globally significant species such as blue whale and sooty shearwater; endangered species such as southern right whale; and unique biological communities such as cold water corals.

Figure 7 in the Habitat Criterion above indicates particularly high value areas for these species have relatively little overlap with the bulk of the salmon industry in Regions X and XI, but because Chilean salmon farming has experienced an explosive growth in the past two decades, interactions between sea lions and this industry have increased. Although now dated, in 1997, Sepulveda et al. (2005) found that nearly 90% of the Chilean salmon farms in Los Lagos region had reported attacks by sea lions. While predator nets are used, they are not always effective (Vilata et al. 2010).

Of the two South American pinniped species found in this region, there are no reports of the fur seal (*Arctocephalus australis*) preying on farmed salmon in Chile, probably because it feeds mainly offshore. In contrast, the sea lions (*Otaria flavescens*) usually feed in coastal waters predominantly on demersal and pelagic fish (Vilata et al. (2010) and references therein).

Some types of birds are attracted in high numbers to farm sites, for example, the observed abundance of omnivorous diving and carrion-feeding birds increase twofold to fivefold in some

areas with salmon farms compared with control areas without farms (A Buschmann, et al. 2006). It is likely that there are some entanglements and drowning, but this is not considered likely to negatively affect population sizes.

A ban on the lethal control of sea lions was extended to January 2016 (Subpesca Decree No. 112, January 22, 2013), but exceptions could be made in the case of imminent threat to human safety. The estimated Chilean population of sea lions in Region X is over 35,000 and over 10,000 in Region XI, and reported as stable (Oliva et al. 2009, Sepúlveda et al. 2011, Vilata et al. 2010).

No data on lethal control were made available by Sernapesca, and it is not known if predator mortality data are collected or reported. In other salmon farming regions globally, seal and sea lion mortalities have been considerable[27], but are not currently thought to significantly affect population numbers. In Chile's Region X, the population of sea lions seems to be largely stable (Sepulveda et al. 2011) and, even though it is considered likely that some lethal control takes place and some sea lions will become entangled, the numbers are not considered likely to significantly affect the population size.

Wildlife and Predators Criterion - Conclusions and Final Score

The final score is -4 out of -10 as wildlife mortalities are considered to occur (e.g., by entanglement), but the numbers do not significantly affect the population size.

[27] Scotland http://www.scotland.gov.uk/Topics/marine/Licensing/SealLicensing
British Columbia http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/mar_mamm-eng.htm

Criterion 10X: Escape of Unintentionally Introduced Species

A measure of the escape risk (introduction to the wild) of alien species other than the principle farmed species unintentionally transported during live animal shipments

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.

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	8.00	
F10Xb Biosecurity of source/destination	8.00	
C10X Escape of unintentionally introduced species Final Score	**-0.40**	**GREEN**

Salmon production in Chile has suffered greatly from the introduction of pathogens such as ISA, but without native species of vulnerable salmonids in Chile, the risks to wild populations are low. The importation of eggs continues, but is greatly reduced as national Chilean egg production has become established. The sources and destinations of the egg movements (tank-based hatcheries) are now considered to have moderate-high biosecurity and, therefore, the final score for Factor 6.2X is a minor deduction of -0.4 out of -10.

Justification of Ranking

The high profile ISA problems clearly demonstrated the introduction and dissemination of a non-native virus into and throughout Chile's production regions. Although the original entry of ISA is still debatable, the import of eggs is most frequently implicated, (Vike et al. 2009) and the movement of fish from hatcheries and smolt sites to the various on-growing regions is implicated in its spread within Chile (Alvial et al. 2012). Avendaño-Herrera et al. (2014) provide a similar example for the bacterial pathogen *Flavobacterium psychrophilum*, noting the presence and countrywide distribution in Chile is a direct consequence of local fish farming practices that relied, until recently, on massive imports of fish eggs (e.g., 78 million of eggs in 2012) and where mixed-species farms and fish transportation across the country are common.

Although the ecological impacts of the ISA virus or other introduced viruses (e.g., Piscine Reovirus, PRV; Kibenge et al. 2013) beyond the farms may not be significant (see Criterion 7), this pathogen has received the most attention and study, due to the scale of commercial impacts. However, it seems likely that other introduced pathogens that might impact local wild fish of ecological importance (but perhaps not commercial) would also be introduced and disseminated, but not receive the same scientific attention.

Factor 10Xa International or Trans-waterbody Live Animal Shipments

The dominant international movement of live "fish" has been the import of salmon eggs to Chile from Europe. Figure 15 shows the source of salmon eggs in Chile from 1984 to 2011 was dominated by imports prior to 1998. Since then, imports become a minor part of total egg production as local hatcheries developed, but due to overall increases in production, egg

imports reached a peak of over 200 million in 2008 at the pre-ISA peak of production. Avendaño-Herrera et al. (2014) reported the importation of 78 million eggs in 2012 (of unknown species composition), and industry media[28] reported 52.3 million egg imports in 2013 of which half were Atlantic salmon.

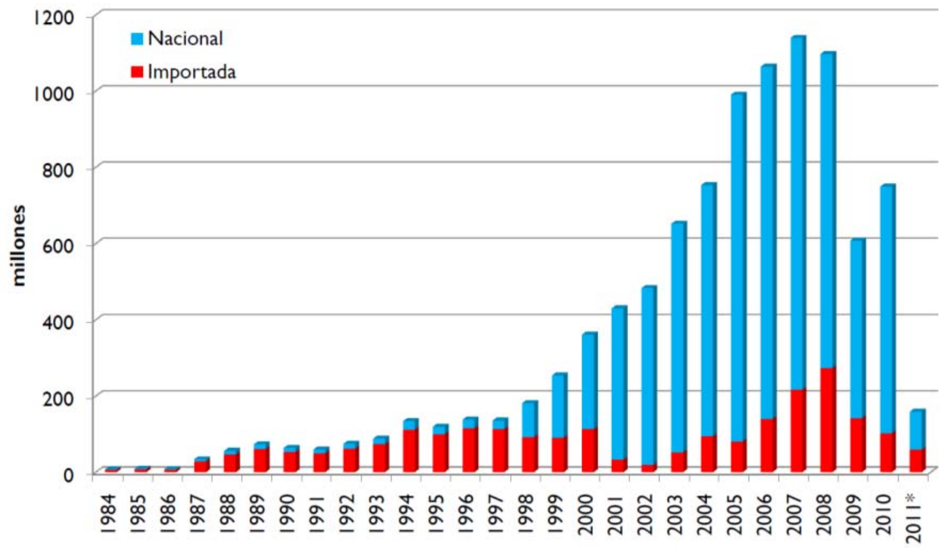

Figure 15. Aquabench data showing the source (national or imported) and number of eggs produced; quoted in Dempster 2011. Data for 2011 is from January to April.

Movements of live fish within Chile (from freshwater hatcheries and smolt production units to the coastal grow out sites) are still a fundamental part of the production model. Martinez-Lopez et al. (2014) note the movements of live or harvested fish, or their by-products may have played an important role in the spread of ISA, but movements are now controlled in health management zones (Alvial et al. 2012).

It is clear from hatchery and site visits in Chile that the maturing industry is becoming more self-sufficient in terms of higher biosecurity, and local egg and smolt production, and the initially poor biosecurity control has improved (discussed in Factor 6.2Xb below). It is not known if coho salmon eggs are imported in a different way from Atlantic salmon, and both species are treated the same in this criterion.

For the most recent, full data year of 2010 (Figure 15), the percentage of eggs imported into Chile is estimated to be 12%, while at risk of being non-representative of current production, therefore, 12% of Chilean salmon production is assumed to be reliant on the international movement of live eggs (score = 8 out of 10).

[28] Intrafish January 31 2014: Chile Atlantic salmon production up 23% in 2013.

Factor 10Xb Biosecurity of Source/Destination

Prior to, and during the ISA outbreak, the importation of eggs was poorly regulated; there was poor sanitary control on farms and the movement of live fish within Chile was uncontrolled (Alvial et al. 2012).

However, along with many poor aspects of the industry pre-ISA, there have been significant resulting changes. Measures introduced voluntarily, and then at the regulatory level after ISA include (from Alvial et al. 2012):

- A ban on movement of smolts from zones of poor sanitary condition to zones of better sanitary condition
- No movement of fish after salt water entry
- Restriction of egg imports. No importation of eggs from countries with infectious salmon anemia virus (ISAV) or pancreas disease (PD)

In addition to these measures, the biosecurity of egg production in the industry as a whole has generally improved, and tank-based hatcheries and domesticated broodstocks are considered to be relatively biosecure (score of 8), according to the Seafood Watch criteria.

Criterion 10X - Conclusions and Final Score

Overall, the importation of live eggs has decreased considerably and is now a minor component of total egg supply. The hatcheries supplying the eggs are considered to be relatively biosecure and able to supply eggs free of notifiable diseases. This results in a minor negative penalty of -0.4 out of -10.

Overall Recommendation

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

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

Atlantic salmon

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.11	YELLOW	
C2 Effluent	2.00	RED	NO
C3 Habitat	3.93	YELLOW	NO
C4 Chemicals	CRITICAL	RED	YES
C5 Feed	4.23	YELLOW	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8 Source	10.00	GREEN	
C9X Wildlife mortalities	-4.00	YELLOW	NO
C10X Introduced species escape	-0.40	GREEN	
Total	**29.88**		
Final score	**3.73**		

OVERALL RANKING

Final Score	3.73
Initial rank	YELLOW
Red criteria	2
Interim rank	RED
Critical Criteria?	YES
Final Rank	AVOID/RED

Coho salmon

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.11	YELLOW	
C2 Effluent	2.00	RED	NO
C3 Habitat	3.93	YELLOW	NO
C4 Chemicals	CRITICAL	RED	YES
C5 Feed	4.23	YELLOW	NO
C6 Escapes	3.00	RED	NO
C7 Disease	4.00	YELLOW	NO
C8 Source	10.00	GREEN	
9X Wildlife mortalities	-4.00	YELLOW	NO
10X Introduced species escape	-0.40	GREEN	
Total	**28.88**		
Final score	**3.61**		

OVERALL RANKING

Final Score	3.61
Initial rank	YELLOW
Red criteria	3
Interim rank	RED
Critical Criteria?	YES
Final Rank	AVOID/RED

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

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

Disclaimer

Seafood Watch® strives to ensure all our Seafood Reports and the recommendations contained therein are accurate and reflect the most up-to-date evidence available at time of publication. All our reports are peer reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science or aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch program or its recommendations on the part of the reviewing scientists. Seafood Watch is solely responsible for the conclusions reached in this report. We always welcome additional or updated data that can be used for the next revision. Seafood Watch and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[29] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

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

Seafood Watch will:

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

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

practices for some criteria may lead to more energy intensive production systems (e.g. promoting more energy intensive closed recirculation systems)

Once a score and rank has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ranks 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.

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 Criteria document for a full explanation of the criteria, calculations and scores. Yellow cells represent data entry points.

Criterion 1: Data quality and availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	7.5	7.5
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	7.5	7.5
Predators and wildlife	Yes	2.5	2.5
Chemical use	Yes	7.5	7.5
Feed	Yes	5	5
Escapes, animal movements	Yes	2.5	2.5
Disease	Yes	7.5	7.5
Source of stock	Yes	7.5	7.5
Other – (e.g. GHG emissions)	No	0	n/a
Total			**55**

C1 Data Final Score	6.1	YELLOW

Criterion 2: Effluents

C2 Effluent Final Score	**4.00**	**YELLOW**

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**5**

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Factor 3.2a - Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Moderately	0.5
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Partly	0.25
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Moderately	0.5
4 - Are high value habitats being avoided for aquaculture siting? (i.e. avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Mostly	0.75
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	No	0
		2

Factor 3.2b - Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Mostly	0.75
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Moderately	0.5
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Partly	0.25
4 - Is the enforcement process transparent - e.g. public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	Mostly	0.75
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	No	0
		2.25

F3.2 Score (2.2a*2.2b/2.5)	**1.80**

C3 Habitat Final Score	**3.93**	**YELLOW**
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	**Score**	
C4 Chemical Use Score	**CRITICAL**	
C4 Chemical Use Final Score	**CRITICAL**	**RED**
Critical?	YES	

Criterion 5: Feed

5.1. Wild Fish Use
Factor 5.1a - Fish In: Fish Out (FIFO)

Fishmeal inclusion level (%)	22
Fishmeal from by-products (%)	15
% FM	18.7
Fish oil inclusion level (%)	11
Fish oil from by-products (%)	15
% FO	9.35
Fishmeal yield (%)	23
Fish oil yield (%)	5
eFCR	1.3
FIFO fishmeal	1.06
FIFO fish oil	2.43
Greater of the 2 FIFO scores	2.43
FIFO Score	**3.92**

Factor 5.1b - Sustainability of the Source of Wild Fish (SSWF)

SSWF	-6
SSWF Factor	-1.45

F5.1 Wild Fish Use Score	**2.46**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	39
eFCR	1.3
Feed protein from NON-EDIBLE sources (%)	40.9
Feed protein from EDIBLE CROP sources (%)	27.1
Protein OUTPUTS	
Protein content of whole harvested fish (%)	16.9
Edible yield of harvested fish (%)	62.3
Non-edible by-products from harvested fish used for other food production	100
Protein IN	26.03
Protein OUT	16.9

Net protein gain or loss (%)		-35.1
	Critical?	NO
F5.2 Net protein Score	**5.00**	

5.3. Feed Footprint

5.3a Ocean area of primary productivity appropriated by feed ingredients per ton of farmed seafood

Inclusion level of aquatic feed ingredients (%)	33
eFCR	1.3
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	11.16

5.3b Land area appropriated by feed ingredients per ton of production

Inclusion level of crop feed ingredients (%)	38.7
Inclusion level of land animal products (%)	23
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	1.3
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.52

Value (Ocean + Land Area)	**11.67**

F5.3 Feed Footprint Score	**6.00**

C5 Feed Final Score	**4.23**	**YELLOW**
	Critical?	**NO**

Criterion 6: Escapes – Atlantic Salmon

6.1a. Escape Risk

Escape Risk	**2**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	13
Recapture & Mortality Score	0.13
Factor 6.1a Escape Risk Score	**3.04**

6.1b. Invasiveness

Part A – Native species

Score	n/a

Part B – Non-Native species

Score	**1.5**

Part C – Native and Non-native species

Question	**Score**
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	To some extent
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	No
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	No
Do escapees have some other impact on other native species or habitats?	No
	4

F 6.1b Score	**6**

Final C6 Score	**4.00**	**RED**
	Critical?	**NO**

Criterion 6: Escapes – Coho

6.1a. Escape Risk

Escape Risk	**2**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	13
Recapture & Mortality Score	0.13
Factor 6.1a Escape Risk Score	**3**

6.1b. Invasiveness

Part A – Native species

Score	n/a

Part B – Non-Native species

Score	**1**

Part C – Native and Non-native species

Question	**Score**
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	Yes
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	No
Do escapees modify habitats to the detriment of other species (e.g. by feeding, foraging, settlement or other)?	No
Do escapees have some other impact on other native species or habitats?	No
	1.5

F 6.1b Score	**4.5**

Final C6 Score	**3.00**	**RED**
	Critical?	**NO**

Criterion 7: Diseases

Pathogen and parasite parameters	**Score**	
C7 Biosecurity	4.00	
C7 Disease; pathogen and parasite Final Score	**4.00**	**YELLOW**
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	**Score**	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	100	
C8 Source of stock Final Score	**10**	**GREEN**

Exceptional Criterion 9X: Wildlife and predator mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**-4.00**	**YELLOW**
Critical?	NO	

Exceptional Criterion 10X: Escape of unintentionally introduced species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	8.00	
F10Xb Biosecurity of source/destination	8.00	
C10X Escape of unintentionally introduced species Final Score	**-0.40**	**GREEN**

Appendix 1

Smolt Production in Lakes.
A 2007 WWF report (Leon-Munoz et al. 2007) highlighted effluent concerns regarding the use of freshwater lakes for salmon smolt production. It stated, "*Over the last 25 years, salmon farming has used lakes as the primary media for smolt production, becoming—along with urban sewage— the most significant point source of nutrient inputs to these ecosystems.*" From the same report:

> The biogeographical isolation and the distinctive environmental characteristics of Chile's freshwater systems have resulted in a unique ecological composition with very high levels of endemism (species that are globally unique). Ninety-three percent of native freshwater fish species are threatened, 40% are endangered, and only two species are classified as out of danger. In addition to biodiversity values, lakes provide a range of ecosystem services and are highly valued national and global resources. Salmon farming is one of the only activities that has a measurable impact on the water column and lake or river bottom around installations

Data from the analysis company Aquabench referred to in Dempster (2011) show a dramatic change in the use of lakes for Atlantic salmon smolt production since 2007; at that time only 20% of smolts were produced in tank-based hatcheries while the rest was split between lakes and estuaries. Four years later in 2011, 100% of Atlantic salmon smolts were produced in enclosed hatcheries, demonstrating the industry's ability to evolve and avoid this potential impact. However, the sites remained valid under ownership of the salmon companies and, it is interesting to note that, in 2012, there were again a number of active salmon smolt production sites (four) operating in Chile's freshwater lakes. This is expected to be in response to the increasing demand for smolts to expand production at a level which the tank-based hatcheries cannot currently supply. Therefore the potential for impacts in lakes remains.

The production of coho salmon has not followed this decline in use of lakes; approximately 75% of coho smolts are still produced in cages in Chile's freshwater lakes (in 2011) and, therefore, continue the concerns of Leon-Munez et al. (2007).